Feature processing and feature integration in unconscious processing

A Study with chess novices and experts

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Zusammenfassung

Die folgende Arbeit beschäftigt sich mit dem Einfluss von Erfahrung (im Sinne von Expertise) auf die unbewusste Verarbeitung von perzeptuellen Merkmalen. Im theoretischen Teil beschreibe ich zunächst das Paradigma des Subliminalen Primings; eine Methode, um zu untersuchen wie Reize, die wir nicht bewusst wahrnehmen können, dennoch unsere Handlungen beeinflussen. Die Aktivierung von semantischen Antwortkategorien, der Einfluss von gelernten Reiz-Reaktions-Verbindungen, sowie die Aktionsauslösung durch programmierte Reiz-Reaktions-Verbindungen sind die drei am weitesten verbreiteten Hypothesen, um zu erklären weshalb Reaktionen unbewusst ausgelöst werden können. Daneben kann auch die Übereinstimmung von perzeptuellen Merkmalen die unbewusste Reaktionsbahnung beeinflussen. Anhand der Merkmale Lokation und Form, stelle ich sodann vor, welche Belege es bislang für Perzeptuelles Priming gibt. Der zweite Abschnitt des Theorieteils setzt sich mit der Literatur über perzeptuelle Überlegenheit von Experten auseinander, was exemplarisch an drei Bereichen von Expertise gezeigt wird – dem Spielen von Egoshootern auf dem Computer, was mit einer eher generellen Form von perzeptueller Expertise einhergeht, Radiologen, die eine natürlichere Form von Expertise zeigen und das Spiel Schach, das als Drosophila der Psychologie angesehen wird.

Im empirischen Teil stelle ich neun Experimente vor, in denen eine subliminale Schachentdeckungsaufgabe eingesetzt wurde. In Experiment 1 zeigen Schachexperten im Gegensatz zu Schachnovizen sublimials Reaktionspriming.

Das heißt Schachexperten sind in der Lage in unbewusst präsentierten Schachdigrammen „zu erkennen“ ob der König im Schach steht oder nicht. Die Ergebnisse von Experiment 2 legen nahe, dass erworbene perzeptuelle Chunks und nicht die Fähigkeit Merkmale unbewusst zu integrieren, ausschlaggebend für die unbewusste Schachentdeckung bei den Experten war, da Schachexperten kein Reaktionspriming für einfachere Schachdiagramme zeigen, bei denen jedoch eine unvertraute Klassifikation gefordert ist. Mit einer komplexeren Schachentdeckungsaufgabe deuten die Ergebnisse von Experiment 3 darauf hin, dass auch Experten nicht in der Lage sind, perzeptuelle Merkmale parallel zu verarbeiten, bzw. dass Schachexperten, wenn viele verschiedene Schachdiagramme präsentiert werden, keine spezifischen Erwartungen bilden können, die aber offensichtlich notwendig sind um Priming auszulösen.

Die Absicht von Experiment 4-9 war es, bei Novizen die unbewusste Verarbeitung der Merkmale Lokation und Form weiter zu erforschen. In Experiment 4 und 5 übertraf das Perzeptuelle Priming, das durch die Übereinstimmung der einzelnen Merkmale Lokation und Form ausgelöst wurde, das auf Semantik beruhende Reaktionspriming. Experiment 6 und 7 zeigen das (im Gegensatz zum Formpriming) der Lokationspriming-Effekt relativ robust ist und auch für eine unerwartete Form oder Farbe auftritt. In Experiment 8 wurden Lokations- und Formpriming direkt einander gegenübergestellt, wobei Formpriming zusätzlich mit Reaktionspriming verbunden war. Lokationspriming war abermals stärker als Formpriming. Schließlich verdeutlicht Experiment 9 das es auch mit der subliminalen Schacherkennungsaufgabe bei Novizen möglich ist, Reaktionspriming auszulösen, wenn die konfundierenden Einflüsse der Merkmale Lokation und Form beseitigt werden.

In der Gesamtdiskussion fasse ich zunächst die Ergebnisse der Arbeit zusammen. Im Anschluss daran diskutiere ich mögliche zugrundeliegende Mechanismen unterschiedlicher subliminaler Wahrnehmung von Experten und Novizen. Dann betrachte ich die subliminale perzeptuelle Wahrnehmung von Novizen näher, wobei der Fokus auf dem Einfluss der Merkmale Lokation und Form liegt. Schlussendlich stelle ich mit dem Konzept von programmierten Reiz-Reaktions-Verbindungen einen Ansatz vor, der geeignet ist, um die unterschiedlichen Ergebnisse der vorliegenden Arbeit zu erklären.

Abstract

The scope of the present work encompasses the influence of experience (i.e. expertise) for feature processing in unconscious information processing. In the introduction, I describe the subliminal priming paradigm, a method to examine how stimuli, we are not aware of, nonetheless influence our actions. The activation of semantic response categories, the impact of learned stimulus-response links, and the action triggering through programmed stimulus-response links are the main three hypotheses to explain unconscious response activation. Besides, the congruence of perceptual features can also influence subliminal priming. On the basis of the features location and form, I look at evidence that exists so far for perceptual priming. The second part of the introduction reviews the literature showing perceptual superiority of experts. This is illustrated exemplarily with three domains of expertise – playing action video games, which constitutes a general form of perceptual expertise, radiology, a more natural form of expertise, and expertise in the game of chess, which is seen as the Drosophila of psychology.

In the empirical section, I report nine experiments that applied a subliminal check detection task. Experiment 1 shows subliminal response priming for chess experts but not for chess novices. Thus, chess experts are able to judge unconsciously presented chess configurations as checking or nonchecking. The results of Experiment 2 suggest that acquired perceptual chunks, and not the ability to integrate perceptual features unconsciously, was responsible for unconscious check detection, because experts' priming does not occur for simpler chess configurations which afforded an unfamiliar classification. With a more complex chess detection task, Experiment 3 indicates that chess experts are not able to process perceptual features in parallel or alternatively, that chess experts are not able to form specific expectations which are obviously necessary to elicit priming if many chess displays are applied.

The aim of Experiment 4-9 was to further elaborate on unconscious processing of the single features location and form in novices. In Experiment 4 and 5, perceptual priming according the congruence of the single features location and form outperformed semantically-based response priming. Experiment 6 and 7 show that (in contrast to form priming) the observed location priming effect is rather robust and is also evident for an unexpected form or colour. In Experiment 8, location and form priming, which was additionally related to response priming, were directly compared to each other. Location priming was again stronger than form priming. Finally, Experiment 9 demonstrates that with the subliminal check detection task it is possible to induce response priming in novices when the confounding influences of location and form are absent.

In the General discussion, I first summarized the findings. Second, I discuss possible underlying mechanisms of different subliminal perception in experts and novices. Third, I focus on subliminal perceptual priming in novices, especially on the impact of the features location and form. And finally, I discuss a framework, the action trigger account that integrates the different results of the present work.

Introduction

When we look around in our modern and civilized world, we see many abstract but meaningful things, such as symbols, signs, letters, words, or numbers. Although the gist of them usually comes to our mind almost immediately, the meaning of these stimuli depends on the specific conjunction of different features. For example, the meaning of a fist with an outstretched thumb depends on its orientation. Likewise, the sequence of two letters is crucial for the meaning of a word (e.g. “am” versus “ma”), and an algebraic sign before a number defines its value (a plus makes it positive, a minus makes it negative). Over the years, the acquaintance of many of these stimuli has become automated so that we normally no longer realize that they consist of different features. Instead, we know what is meant and how to respond to this information. Thus, it seems to be that visual information that is composed of different features is extracted almost inevitably and very easily.

However, the integration of different features sometimes has its limits. When objects are presented very briefly and attention is unfocused, the perception of illusionary conjunctions of their features can be elicited. In a study by Treisman and Schmidt (1982), for example, a blue X, a green T, and a red O were presented simultaneously for 200 ms while attention was directed elsewhere. In a substantial number of trials, participants wrongly reported having seen instead, for example, a red X, a green O, or a blue T. Moreover, when we look at unfamiliar stimuli, the impression of single features often dominates the general view. For most people from the Western world, the Japanese character 家 looks like a futuristic conglomerate of a square and several lines, whereas the Japanese almost immediately perceive the meaning “house” when they read the respective character. Hence, this evidence suggests that feature integration depends on the one hand on certain viewing circumstances like processing time or allocation of attention and on the other hand on familiarity with the respective stimuli, or expertise.

The aim of this work was to explore in more detail how these two factors influence feature processing and feature integration. Concerning the first factor, one way to challenge the processing of complex visual information to its limits, is to examine which stimuli have the power to activate responses outside of conscious awareness with the subliminal priming paradigm. Concerning the latter factor, the expertise approach allows a systematic comparison of the performance of people who posses a different amount of experience with the presented stimuli.

Therefore, the method and the conditions of subliminal response priming as well as perceptual priming are described initially, followed by a review of the perceptual superiority of experts, before on the basis of the game of chess nine experiments are reported and their results discussed.

1. Subliminal priming

Over 100 years ago, Münsterberg (1889/1890; cited after Neumann & Klotz, 1994) already suggested that a stimulus may determine a motor response before or even independent from its conscious perception. Depending on which or whether a motor response is activated, it is possible to infer in which way unconsciously perceived features have been processed.

Meanwhile, the method of masked priming (see Kouider & Dehaene, 2007 for a detailed review) has become a well established paradigm to explore the extent and limits of unconscious stimulus processing. In the masked priming paradigm, participants usually perform a speeded two-choice reaction time task, in which one half set of target stimuli is assigned with a left response whereas the other half is assigned with a right response. A typical task, for example, is to decide whether a square (or diamond) is presented on the left or right in a horizontally arranged stimulus pair (Neumann & Klotz, 1994; Klotz & Neumann, 1999). The target is preceded by a prime stimulus, presented very briefly and masked to prevent conscious perception. Nonetheless, the subliminal prime influences the response to the target systematically. Participants respond faster when prime and target belong to the same response category (congruent trial) than to different response categories (incongruent trial). This so-called congruency or priming effect emerges as a consequence of unconscious perception. It may result either because the prime (pre)activates the same response as the target and facilitates responding because of motor pre activation. Or it may result because the prime and the target are perceptually similar and the prime facilitates target identification. In the following these two alternatives are discussed under the terms "response priming" and "perceptual priming".

1.1. Response priming

In general, response priming is indicated by faster and more accurate responses when prime and target afford the same response (congruent trial) rather than different responses (incongruent trial). It is assumed that the prime (pre)activates the response to the target, because it is associated with one or more of the (already experienced or expected) targets. The strongest evidence for this notion comes from neuroimaging and LRP (lateralized readiness potential**)** studies showing that subliminal primes have the power to elicit neural activity in the motor cortex and to (pre)activate a response up to a motor level with a left or right hand (Dehane et al., 1998, Eimer & Schlaghecken, 1998, Leuthold & Kopp, 1998; Verleger, Jaskowsky, Aydemir, van de Lubbe, & Groen, 2004). A response priming effect has also been reported with behavioral measures in many different studies using a large scale of stimuli - meaningful material like letters (Elsner, Kunde, & Kiesel, 2008; Heinemann, Kiesel, Pohl, & Kunde, 2010; Kiesel, Kunde, & Hoffmann, 2007a; Reynvoet, Gevers, & Caessens, 2005), words (Damian, 2001; Klauer, Musch, & Eder, 2005, Van den Bussche & Reynvoet, 2007), numbers (Dehaene et al., 1998; Kiesel, Kunde, & Hoffmann, 2006; Kunde, Kiesel, & Hoffmann, 2003; Naccache & Dehaene, 2001), and pictures (Dell' Acqua &

Grainger, 1999; Pohl, Kiesel, Kunde, & Hoffmann, 2010; Van den Bussche, Notebaert, & Reynvoet, 2009) as well as more abstract stimuli like arrows (Eimer & Schlaghecken, 1998), squares (Jaskowski, Skalska, & Verleger, 2003), rhombuses (Leuthold & Kopp, 1998; Klotz & Neumann, 1999), and boxes with bars (Neumann & Klotz, 1994; Ansorge & Neumann, 2005).

Thus, it has been reliably shown that even rather complex visual stimuli that are presented very briefly and masked can nevertheless be processed unconsciously and lead to subliminal response activation. But how exactly a response is primed is still an actively discussed research topic and at least three accounts stress different mechanisms in the formation of response priming: activation of semantic response categories, learned stimulus-response (S-R) links, and programmed S-R links. Many studies have been conducted in order to distinguish between these three mechanisms of the formation of response priming.

1.1.1. Activation of semantic response categories

Subliminal priming is often interpreted as response priming through semantic stimulus processing. The activation of semantic categories by primes is a widespread explanation for subliminal response priming and it was also the first explanation of unconscious perception in research history (e.g. Marcel, 1983). Following this account, a prime elicits a certain response because task instructions are not only relevant for the categorization of the targets, but are also unconsciously applied to the prime (Dehaene et al., 1998). A masked prime then facilitates the following target categorization because the semantic category is already activated. For example, in a number classification task, responses to congruent prime-target pairs were faster with a small (e.g. 3-4) than with a large (e.g. 1-4) numerical distance between prime and target (Koechlin, Naccache, Block, & Dehaene, 1999; Naccache & Dehaene, 2001; Reynvoet, Caessens, & Brysbaert, 2002). It is inferred that the processing of quantity meaning “cannot be prevented even in situations where it is totally irrelevant” (Naccache & Dehaene, 2001, p. 235). Thus, there is clear evidence that the semantic magnitude and meaning of the prime must have been processed.

Moreover, there are lots of studies in which response priming with primes that were never presented as targets, so-called novel primes, was found using a wide range of stimuli – numbers (e.g. Naccache & Dehaene, 2001), letters (e. g. Reynvoet et al., 2005), words (e. g. Van den Bussche & Reynvoet, 2007), and pictures (e. g. Pohl, et al., 2010). In these studies it was impossible to build up an automatic link between the novel primes and the target (response) because all novel primes were neither consciously presented nor directly associated with a certain response in the experiment.

Another observation that supports the assumption of semantic prime processing is that response priming also survived changes in the notation format between primes and targets. The first report for this strong indication for semantic processing came from Dell`Aqua & Grainger (1999, see Van den Bussche et al., 2009, for a replication). In their experiment, participants had to decide whether a target word denotes a natural or artificial thing. Primes were line drawings of the same concepts as the words in the target set. Although participants had never seen the pictures consciously, responses were faster when prime picture and target words belonged to the same category than to different ones. Additionally, Klauer, Eder, Greenwald, and Abrams (2007) showed that positive and negative prime words elicited small but significant priming effects for targets picturing eight different emoticons. Thus, semantic meaning must have been extracted from the primes and (pre)activated the corresponding response.

Furthermore, Van Opstal, Gevers, Osman, and Verguts (2010) found recently appealing evidence for Dehaene and colleagues' notion "that the prime [is] unconsciously processed according to task instructions, all the way down to the motor system" (1998, p. 597). Participants had to compare whether two target stimuli were either the same or different. Although the primes were taken from a novel and completely distinct category (numbers) than the targets (colour patsches), a congruency effect emerged. To rule out, that this effect is primarily brought up by a perceptually based processing of the primes, a second experiment was conducted were targets were numbers (e.g. 33) and primes were letters – always one in lowercase together with one in uppercase (e.g. mQ). Nonetheless, priming was observed. However, this is only possible, when the semantics of the prime stimuli had been accessed. Thus, these results indicate that algorithms (task sets that were not consciously prepared) can be applied unconsciously[1]

[1] Note: There is also good evidence for 'true' semantic priming in an associative, not response-related manner (e.g. Devlin, Jamison, Matthews, & Gonnerman, 2004; Kiefer & Brendel, 2006; Van den Bussche, Noortgate, & Reynvoet, 2009). However, the present study focuses solely on

To conclude, the fact that novel stimuli as well as stimuli from novel categories to which no conscious links between the stimulus and the response could have been built up, are effective as primes, in addition to the other findings, underlines that unconscious processing functions in an elaborate way and that “unconscious primes activate motor codes through semantics” (Reynvoet et al., 2005, p. 991).

1.1.2. Learned stimulus-response links

However, there is also doubt as to the universal validity of this kind of apparently easy and elaborate processing of unconsciously presented stimuli. In a more restricted view of unconscious cognition, it is thought that subliminal stimuli have the power to trigger responses because of acquired and automated response links between primes and previously experienced targets.

First, some studies demonstrated that the acquisition of stimulus-response (S-R) links was a necessary precondition for prime impact (Abrams & Greenwald, 2000; Damian, 2001). S-R links are formed when participants repeatedly answer to target stimuli (S) with a defined keypress response (R). Stimuli only evoke response priming effects after practise, that is, after the same stimulus has repeatedly been seen and responded to as target. Especially when dealing with

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response priming and perceptual priming. Therefore, this point is not further amplified here (for a more elaborate discussion of the distinction between ‘true’ semantic priming, also called ‘pure’ semantic priming or central priming, from response priming, see Kiesel, Kunde, & Hoffmann, 2007b; Kouider & Dehaene, 2007; Van den Bussche, et al., 2009).

only a small number of different targets from vast as well as diffuse categories, building up S-R (stimulus-response) links between targets and responses seems to be the main mechanism for unconscious response activation (Abrams, 2008a; Abrams & Greenwald, 2000, Exp 3; Damian, 2001; Kiesel, Kunde, Pohl, & Hoffmann, 2006, Exp. 2). For example, Damian (2001) had participants classify twelve words as denoting objects smaller or larger than a 20x20 cm reference frame. Only prime words that were also presented as targets (target primes) elicited a congruency effect that even increased from block to block (indicating that the more practise is given to the stimuli, the stronger the priming effect becomes). Novel prime words that also denoted objects smaller or larger than the reference frame, but were never experienced as targets, did not influence the target responses. In addition, a comprehensive meta-analysis (Van den Bussche, et al., 2009) showed that the greatest priming effects were obtained when it was possible to build up S-R links. Although novel primes elicited priming, congruency effects for target primes were larger than for novel primes.

Second, it has been shown that different features of subliminally presented stimuli are not processed as a whole, but fragmentarily. When the meaning of a word or number is contrasted with feature overlap between primes or parts of them and the set of experienced targets paradoxical response priming effects emerge. Abrams and Greenwald (2000) constructed a set of pleasant and unpleasant words in such a way that identical letter chains between prime and target words were always associated with the opposite response category. For example, the words *smut* and *bile* - both with an unpleasant connotation - were used as targets. The word *smile* was presented as prime. It has a pleasant connotation (within the categorization task, the “pleasant” response would have been necessary), but at the same time its letters stem from the two unpleasant target words. In an affective evaluation task, perceptual similarity of the letter chains between the prime and the experienced target set, and not the meaning of the prime, was decisive for the direction of the priming effect. That is, contrary to its positive connotation, the prime *smile* facilitated responding to the negative connotated targets, after participants had repeatedly classified the unpleasant words *smut* and *bile* (see also Abrams, 2008b, for the same finding with a size classification task). A similar result was observed with two-digit numbers (Greenwald, Abrams, Naccache, & Dehaene, 2003). Participants had to classify two-digit numbers as smaller or larger than 55. Targets for the smaller category were composed of the four digits 1, 4, 6, and 9 (e.g. 16; 49) and targets for the larger category were composed of the four digits 2, 3, 7, and 8 (e.g. 73; 82). The digits of each group were used as targets for the one and at the same time as primes for the other response, respectively (e.g. 16, 49; 73, 82 as targets and 64, 91; 27, 38 as primes). As a consequence, for example the prime number 91 did not facilitate responses to the target numbers whose values were also larger than 55 (73, 82), but to the target numbers smaller than 55 (16, 49) because of its similarity regarding digits (9 and 1). Thus, these primes had no impact on the targets according to their two-digit number value, but according to their single digits, which were associated with targets from the opposite response.

Taken together, these results point out that response priming does not necessarily derive from unconscious stimulus categorization, rather than from acquired S-R mappings. Moreover, these studies demonstrate that unconsciously presented stimuli are not processed regarding their meaning as a whole. Instead, response facilitation depends on the matching of elementary features in the prime stimulus (single letters or digits) to the learned response to these features in the target set. Because it is well-known that this kind of feature overlap can interfere with (a semantic interpretation of) response priming, stimulus sets in priming experiments have been carefully constructed in such a way that primes and targets (especially those assigned to the same response) share no, or few, perceptual features (e.g. Abrams, 2008b; Klauer et al., 2007). So, in order not to leap to conclusions based on these significant results, it is important to rule out that “priming effects … arose not through semantic analysis of the primes, but through subword processing of orthographic elements that triggered category associations established in practice” (Abrams, 2008b, p. 351).

1.1.3. Programmed S-R links

Programmed S-R links are expected to build up when participants intentionally prepare for a task-defined response (action trigger account, see Kunde, et al., 2003; Kiesel, et al., 2007b; Kiesel, et al., 2006). Unconscious response priming is explained with a two-process model which in a sense combines the ideas of priming via activation of semantic categories and automatic S-R links. It is assumed that primes trigger responses to the extent they fit to formed action release conditions. In a first processing step, participants are programming S-R links by categorizing stimuli they expect in the experimental context in appropriate and non-appropriate release conditions for the required responses. Which stimuli are expected and therewith serve as action triggers depends on instructions and experienced task requirements. This first processing step involves semantic analysis of the expected or experienced stimuli, if the task requires a semantic classification. However, in contrast to the activation of semantic categories by the prime, semantic analysis is restricted to expected stimuli. Unconsciously presented stimuli are not necessarily processed semantically. The second processing step then occurs online in each trial. Here, stimuli are compared with the action release conditions. If they match, the prepared action is triggered automatically, causing congruency effects. Primes that do not fit to the existing action triggers remain ineffective. Thus, in line with the account of learned S-R links, there is automatic response activation if primes fit to the release conditions of an existing action trigger. But in contrast to this account, the S-R links are established intentionally and do not require repeatedly responding to consciously seen target stimuli.

According to the account of programmed S-R links, congruency effects of novel prime stimuli should depend on whether the prime stimuli belong to the trigger set or not. Indeed, Kunde and colleagues (2003, Exp. 2) showed that the occurrence of subliminal priming depends on the supraliminally presented target set. When participants categorized the target digits 3, 4, 6, and 7 as smaller or larger than 5, the novel primes 1, 2, 8, and 9 did not evoke congruency effects. Contrarily, when participants categorized the digits 1, 4, 6, and 9 as smaller or larger than 5, the novel primes 2, 3, 7, and 8 yielded priming effects (Exp. 1 of Kunde et al, 2003, replicating findings of Naccache & Dehaene, 2001). Kunde and colleagues (2003) referred to the special mental representation of numbers that form an intimately integrated representation often described as a mental number line (e.g., Galton, 1880; Göbel, Walsh, & Rushworth, 2001). They concluded that when the digits 1 and 4 are recruited as action triggers for one response, it seems likely that the mentally enclosed numbers 2 and 3 might enter the same trigger set. But when the digits 3 and 4 are selected for one response, the on average more distant and not enclosed numbers 1 and 2 are not considered as action triggers.

Following this notion, novel primes can become action triggers if they are closely related to the stimuli that are recollected as trigger events because they are experienced as targets. With a small target set, neighbours are only activated if they are tightly linked with the targets. But with a large target set, instances from the same semantic space are also activated. Kiesel and colleagues (2006) had participants categorize objects denoted by words as being smaller or larger than a soccer ball. When only four words were presented as targets, priming was confined to primes that were presented as targets. Even novel primes which were semantically related to a target word (e.g. prime fork – target knife) were ineffective. However, when the size of the target set increased to forty words, priming transferred to novel primes. Thus, the size of the target set had a decisive influence on the processing of novel primes. When there was a large set of target words, then different words - also words not seen as targets (novel primes) – were considered as release conditions. So it is conceivable that after having experienced for example the target words “car”, “ship”, and “bus”, other words naming vehicles, such as “train” are recollected as well.

The two basic ideas that stimulus expectations serve for action control and that anticipating stimuli determines their (unconscious) processing are also integrated in a more general way in the concept of direct parameter specification (Ansorge & Neumann, 2005; Neumann, 1990; Neumann & Klotz, 1994; Klotz & Neumann, 1999). In the concept of direct parameter specification participants’ intentions are crucial. It is assumed that “participants search for information in order to specify free parameters within the currently active intention” (Ansorge & Neumann, 2005; p. 764).

To sum up, according to the account of programmed S-R links, unconsciously presented stimuli are able to trigger a motor response when they fit to participants’ expectations or intentions.

Hence, there is a lot of empirical evidence, both for the activation of semantic categories and for learned as well as programmed S-R links. It is most likely that all three forms of response priming are possible and that they contribute differently to priming effects, depending on the concrete experimental design. A meta-analysis (Van den Bussche, et al., 2009) comparing the impact of semantic relations and automatic stimulus-response mappings on subliminal priming, showed that the greatest priming effects were obtained when it was possible to build up learned S-R links.

1.2. Perceptual priming

The finding, that in direct comparison the influence of learned S-R links seems to be stronger than the influence of the activation of semantic response categories, agrees with studies demonstrating paradoxical semantic priming effects, observed when primes shared more letters or digits with targets from the opposite instructed semantic classification than with targets from the same category (Abrams, 2008b; Abrams & Greenwald, 2000; Greenwald et al., 2003). However, instead of the activation of a learned (S-R) response by the prime, an alternative explanation is conceivable. For example, in Abrams' and Greenwalds' second experiment (2000), contrary to its positive meaning, e.g. the prime *smile* facilitated responding to the negatively connotated targets, where the target comprised amongst others the unpleasant words *smut* and *bile*. What is not quite clear is whether the prime *smile* facilitated responding to all negatively connotated targets (e.g. *crime* and *frown*) or only to target words that sharee identical letter strings (e. g. *smut* and *bile*). A detailed analysis concerning this point has not been published yet. In all three studies that demonstrated paradoxical semantic priming effects, a limited set of stimuli was used – 8 word targets (Abrams, 2008b), 24 word targets (Abrams & Greenwald, 2000), 8 two-digit number targets consisting of only 4 different digits (Greenwald et al., 2003). Thus, it is possible that the observed effect derives predominantly or even only from trials where features of prime and target overlap, or that, at least, the priming effect is boosted when prime and target within a trial share part-stimulus features. If that is the case, then the observed priming effect is less due to learned S-R links than to perceptual priming, that is, overlapping perceptual features between prime and target within the same trial.

Perceptual priming through subliminal stimuli may occur when, in a trial, the prime facilitates perception of the target. Following this notion, the prime facilitates target processing and therefore responding to the target becomes faster. If one considers a masked visual prime as cue that includes attributes or properties of the target stimulus, it is conceivable that every feature that the prime and the target share may lead to perceptual facilitation – colour, intensity, orientation, size, location or form (often also referred to as shape or identity). For the purpose of the present study, the influence of the latter two features on perceptual facilitation was explored, because in visual perception location or form are important stimulus features that are often varied in priming studies. However, before I address the evidence that exists so far for perceptual priming through subliminal stimuli, I will begin with a short review of the more general impact of supraliminal cuing of location and form.

In every day life we constantly respond to stimuli in our environment. However, before a response can be selected and executed, the imperative stimulus has to be located and identified first. When we already look or attend to the location where the imperative stimulus will appear subsequent responding is easier because processing can start earlier. For supraliminal stimuli, this phenomenon is well examined. Usually, facilitation effects occur when attention is drawn exogenously (i.e. automatically) to the location of the imperative stimulus before its presentation (Posner, 1980; Posner & Cohen, 1984; Posner, Snyder, & Davidson, 1980). In a typical exogenous cuing experiment, a trial starts with a central fixation followed by an exogenous signal (e.g. an abrupt onset or a singleton) on the right or left side. When the target appears on the cued side, it is a valid trial, when the target appears at the other side it is an invalid trial. Exogenous cues[2] attract attention in a mere automatic way. As a result participants respond faster in valid trials even when the probability for valid and invalid is equal and when the cue has no relevance for the task (e.g. Folk & Remington, 1998, 1999; Posner, 1980; Remington, Folk, & McLean, 2001). This so-called cuing effect occurs even when participants are instructed to ignore the cues (Jonides, 1981). The time-course of this attentional effect that influences responses to target stimuli presented on or nearby the cued location follows usually a biphasic pattern with an early facilitation and a later inhibition (of return) that begins to develop between 200 and 300 ms between cue onset and target presentation (Klein, 2000).

[2] Besides attracting spatial attention exogenously, it is also possible to direct spatial attention endogenously (Posner, 1980; Posner, et al., 1980). In endogenous cuing experiments, a trial starts with a central fixation followed by a central sign which indicates on which side the target is expected. Again the cue can be valid or invalid. Endogenous cues are effective only when they predict the likely position of the target – for example if the cues are valid in 80% of all trials (but see Friesen, Ristic, & Kingstone, 2004, Gibson & Bryant, 2005, Hommel, Pratt, Colzato, & Godjin, 2001, Pratt, Radulesco, Guo, & Hommel, 2010, and Tipples, 2002, for endogenous cuing or reflexive shifts of attention with uninformative cues). However, this paradigm is used to answer other research questions than the scope of the present work and is therefore referred only in a footnote.

Having seen a picture or a word already before its presentation also enhances processing of the following stimulus (Bartram, 1974; Biederman & Cooper, 1991; Jacoby, 1983) This is usually shown with an experiment that consists of two parts. In the first part pictures of objects or words are presented to participants in advance. In the second part, the same stimuli but fragmented or somehow obscured are presented again. Priming is indicated through a higher identification rate and a faster identification response for the previously primed stimuli compared to non primed stimuli. These effects were found for a wide time range between the two stages, lasting from seconds to months (Wiggs & Martin, 1998; Tulving & Schacter, 1990). This phenomenon was originally called (direct or repetition) priming and it is assumed that it “represents a ubiquitious occurance in everyday life” (Tulving & Schacter, 1990, p. 302) as well as that it constitutes a separate form of the traditional memory systems.

It is even possible to cue both – location and form at the same time, as Lambert & Hockey (1986; Exp. 1) demonstrated: One of two different forms (ellipse or diamond) appeared either on the left or the right side of the diagram. A central cue was either neutral or informed in advance about the likely location (a line projecting in one direction) and / or form of the impending stimulus with 66 % validity, respectively. A circle indicated that the imperative stimulus was more likely to be curved, whereas a square indicated that it was more likely to be angular. Thus, these cues were not only predictive but also perceptually similar to the imperative stimulus. The task was to discriminate item orientation (which was vertically or horizontally oriented) so that the cue did not specify any parameters of response execution. Responding to the target was faster if location and form were cued correctly, whereby the effect of the location cue was stronger and more robust (however, see Posner et al., 1980) for location cuing but no form cuing even with predictable letters). Moreover, other experiments which are designed in a way that one type of form is more likely to occur at one distinct location showed that this (more long-term predictivity) had an additional influence on both location cuing (Lambert & Hockey, 1986; Exp. 2-4) and form cuing (Lambert, 1987).

Recently, Marzouki, Grainger and Theeuwes (2008) found that location cuing even modulates the processing of stimuli participants were not aware of. Using the masked repetition priming paradigm, priming effects with letters were only present when a visible cue (presented for a duration of 150 ms and 162 ms before prime onset) was valid but not when it was invalid. Similar results were found in two other studies (Lachter, Forster, & Ruthruff, 2004; Besner, Risko, & Sklair, 2005) with a horizontal rather than a vertical arrangement of the stimuli.

1.2.1. Location priming

With subliminal stimuli, it has been shown that the response to a target stimulus is faster when a subliminal cue has been presented at the same location as the target. For example, McCormick (1997) demonstrated location cuing for cues presented below detection threshold. An X or O was presented on the right or left side of the screen. Participants were instructed to respond to the identity of the letter with a left and right hand key, respectively. Before target presentation, a cue (a vertical bar that was presented visible or invisible) appeared on one of the two sides. Then the target occurred in 85% of the trials on the opposite side and only in 15% of the trials on the same side as the cue. When participants were aware of the cue, they used the given information about target predictability and responded faster when the target occurred on the opposite side. However, when participants were unaware of the cue, the reverse pattern of results was observed. Unaware participants responded faster to the target when it occurred on the same side as the cue rather than the other side. Meanwhile, McCormick's conclusion that (exogenous) “orienting attention without awareness” (McCormick, 1997, p. 168) is possible has been confirmed in other studies that better control for cue (in)visibility and possible influencing factors like task relevance, validity, or SOA (e.g., Ansorge & Heumann, 2006; Ivanoff & Klein, 2003; Lambert, Naikar, McLachlan, & Aitken, 1999; Mulckhuyse, Talsma, & Theeuwes, 2007; see also Mulckhuyse & Theeuwes, 2010 for a critical literature review).

In elaborating determinants of subliminal exogenous cuing, Ansorge, Heumann, and Scharlau (2002), found that in contrast to a visible cue, a masked peripheral cue only elicited cuing effects when it matched the response criterion. More recently, Ansorge, Kiss, and Eimer (2009) showed that only task-relevant features of subliminal stimuli (defined by colour) captured spatial attention, leading to cuing effects similar to what had already been found using unmasked cues (e.g. Folk, Remington, & Johnston., 1992). Following the same line, Ansorge and Heumann (2006) systematically diminished the cue-target match (in terms of the features colour and location) of invisible onset cues. As a result, the cuing effect decreased in the RTs, but not in the Posterior Contralateral Negativity (PCN). The PCN is an electrophysiological measure that reflects the distribution of visospatial attention. In the present study, it indicated the effects of the cues over 200 ms earlier than the measure of the manual reaction time. So, the authors assumed that an “invisible singleton-cue can capture attention in a stimulus-driven manner” (Ansorge & Heumann, 2006, p. 61). However, this initial capture seems to be prone to a rapid deallocation of attention, especially when the perceptual match between cues and experienced targets is small.

On the other hand, Mulckhuyse and colleagues (2007) demonstrated even in the RTs that subliminal spatial cues can “capture attention in a pure exogenous or stimulus driven way” (Mulckhuyse & Theeuwes, 2010, p. 300). That is, undetectable and uninformative cues that were dissimilar to the targets (i.e. one of three placeholders that was presented just 16 ms earlier than the other two), nevertheless attracted attention and led to a cuing effect (see also Ivanoff & Klein, 2003).

Further evidence that a masked prime can function as a cue and therefore the prime initiates a shift of attention to its location comes from another paradigm – the so-called perceptual latency priming (e.g. Scharlau, 2002, 2004; Scharlau & Ansorge, 2003; Scharlau & Neumann, 2003a, 2003b; Steglich & Neumann, 2000). A masked prime precedes one of two targets. When participants judge which of the two targets was presented first (temporal order judgement) they are inclined to perceive the primed target first even if it is presented somewhat later than the other target. The interpretation for this finding is that visual information does not impinge immediately in our consciousness but only after some delay. Among other things some time is required to direct attention to the location of the stimulus. A preceding prime captures attention even before target presentation and therefore facilitates the perception of the target. As a result the target is seen faster, which leads to a subjectively earlier temporal order judgement. Again, perceptual latency priming was only evident when the primes matched to the task-relevant (colour or shape) and therefore intentionally searched-for target features (Scharlau & Ansorge, 2003).

1.2.2. Form priming

There is also evidence that responses to a target stimulus are faster when masked prime and target have the same or a similar form than when they have a different form. Whenever at least two different targets are assigned to the same response, it is possible to compare either the magnitude of priming effects or the direct reaction times between congruent, but not identical, and congruent, identical prime-target pairs. Following this principle, Mattler (2006) used squares with an arrowhead either pointing left, right, up or down as stimuli. Participants had to press one button when the arrow pointed left or right and the other button when the arrow pointed up or down. Before the target, a prime was presented that had the same form as the targets, but was a smaller replica of them. Responses were significantly faster for similar prime-target trials (e.g., an arrow pointing to the left in prime and target square) than for congruent prime-target trials (e.g. an arrow pointing to the left in the prime square and to the right in the target square). A similar pattern of results has been obtained in the number domain (Bodner & Dypvik, 2005; Koechlin, et al.,1999), where participants responded faster to identical prime-target trials (1-1) than to congruent prime-target trials (3-1) or to notation mismatches (one-1). In all of these studies, primes were also targets that were repeated very often, so that participants could have built up S-R links. Although mapped to the same response, responses were even faster to identical prime-target pairs than to merely congruent prime-target pairs. Hence, perceptual form congruence has an additional impact on response congruence. Long lasting subliminal visual priming effects are also possible. Naming accuracy for pictures that were already presented masked before was increased, although the repetition of the same picture occurred 15 minutes and 20 intervening trials later (Bar & Biederman, 1998).

Perceptual similarity between primes and targets may also be one determinant in the masked repetition priming paradigm (Forster & Davis, 1984). Here, participants classify target words and nonwords. The standard result is that responses are easier when the same word is presented as prime as well as target compared to a different word (which is in the sense of response priming a congruent case). Although this effect is also manifest when the prime is presented in lowercase letters and the target in uppercase letters and mainly used to study visual word recognition (see Norris & Kinoshita, 2008), perceptual similarity between single letters or letter strings may contribute to the observed effect (e.g. Bodner & Masson, 1997; Sereno, 1991; however see Bowers, Vigliocco & Haan, 1998, showing that the magnitude of the identity priming effect is not modulated by letter similarity).

To sum up, when prime and target within a trial share perceptual features or are even identical, the prime facilitates sensory processing of the target so that the corresponding target response can be selected earlier. However, most priming experiments so far, did not distinguish between the impact of identical prime-target pairs and the effect of congruent target primes.

2. Perceptual superiority of experts

When we interact with common objects in our environment, we normally do not perceive single features like the location or the form of a stimulus in isolation. Instead, we have a more holistic impression of familiar things on which virtually all people can be considered as experts, such as faces (e.g. Carey, 1992; Tarr & Cheng, 2003), words (e.g. McCandliss, Cohen, & Dehaene, 2003), or letters (e.g. Wong & Gauthier, 2007). For example, when gazing at the painting *Vertumnus* (see Figure 1) by the Italian Renaissancepainter Giuseppe Acrimboldo, at first glance one would see the portrait of a man. It will take a few seconds in observing the picture more closely before it becomes obvious that instead of a portrait of a human person, the whole pictured man – head, face and the upper part of the body - is formed by an artful arrangement of several different fruits and vegetables such as pears, cherries, apples, grapes, olives, and grain spikes (adopted after Hoffmann, 2006, p. 11-4). Similarly, when we look at the letter *d*, usually we do not perceive a curved line and an adjacent straight line on its right side, but the composition of these two features as the letter *d*. The perception of such an integration is not self-evident. This becomes clear, when one considers disorders like prosopagnosia, where the ability to recognize faces is impaired (e.g. Behrmann & Avidan, 2005) or the difficulties of elementary school students or illiterates in learning to read and write.

Figure 1. Vertumnus, a portrait of Rudolf II, painted by Giuseppe Acrimboldo 1591.

Hence, what we see essentially depends on what we know. In the eyes of a member of the Yanomami tribe living in the Amazon rainforest, a mobile phone would look like a corrugated stone or a hand-axe. Of course, beyond this striking and illustrative, though far-fetched example, there are many observations and scientific findings that underline the impact of knowledge on perception. With regard to more special domains where individual engagement varies highly, comparing the performance of people who possess different amounts of experience with the characteristics, functions, and appearance of the respective material also reveals substantial differences.

In contrast to novices who are rather inexperienced in a given domain of expertise, experts show superior performance not only in skills such as problem solving, decision making, short- and long-term recall or self-monitoring (Ericsson &

Smith, 1991; Glaser & Chi, 1988) but also in detection, recognition, processing time and encoding of task-relevant stimuli (Chi, 2006a; Chi, 2006b, Palmeri, Wong, & Gauthier, 2004). Experts can perceive features that novices cannot (Chi, 2006a) and "differences in the performance of experts and non-experts are determined by the differences in the way their knowledge is represented" (Chi, 2006b, p. 23). Taken together, expertise in a task also improves perceptual skills.

However, the scope and the kind of improvement of perceptual processing depend on the nature of the task and the goal of expertise. Objects are represented in a way that success of an action with them is warranted (Hoffmann, 1996) and perceptual learning improves this cognitive representation in service of the task and in order to adapt to the environment. So, changes in conceptual and neuronal representations as well as already in early perceptual processing effectuate that attention is allocated to important features or dimensions, that stimuli or parts of stimuli are processed more efficiently through specialised detectors, that similar stimuli become distinguishable, and that complex configurations can be detected as a single unit (Goldstone, 1998). For example, in a letter search task after intensive training, a formerly looked-for target letter automatically attracted attention even when in the present task it was necessary to ignore it (Shiffrin & Schneider, 1977). Such an inability to voluntarily ignore formerly important features or parts that are no longer task-relevant underlines that the source of representational change is more perceptual than strategic. Additionally, after days of learning to judge the number of dots in repeatedly presented patterns comprising between six to eleven dots, response times became independent from the number of dots for the learned patterns. For new patterns, response times increased with the number of dots, whereby the slope depended on the similarity of the new to the learned patterns (Palmeri, 1997). Moreover, experts usually categorize objects in their domain of expertise (e.g. cars, birds, or dogs) equally fast at subordinate (e.g. “nightingale”) and at basic (e.g. “bird”) level (Tanaka & Taylor, 1991). In contrast, novices are faster in basic than in subordinate level categorization, because the latter obliges novices to look for details that are easier for experts to access. Finally, extensive practise with visually presented novel objects called “greebles”, made of a central part and four protruding parts, resulted finally in configural processing of these objects (Gauthier & Tarr, 1997). After ten training sessions, the greebles were recognized equally fast at different levels of abstraction (individual, family, and gender level). Additionally, greeble experts showed a higher sensitivity to slight changes in the parts of objects that depended on the learned orientation, even when these parts were irrelevant for the instructed task. Thus, categorization training with novel objects led to a pattern of behavioural results (Tarr & Gauthier, 1997) and neural activations (e.g. Tarr & Cheng, 2003) similar to that which is usually observed with faces.

Besides these studies, where expertise was predominantly created in the laboratory by training in up to a few thousand trials, distributed over several days, further insights in experts’ perceptual improvements come from natural domains of expertise. Here, expertise has been acquired through training or experience over years, as in the case of a constant leisure activity or a profession. So, it has been shown in a large variety of domains that perceptual superiority (e.g. pattern recognition) is a fundamental component of expertise – in professional activities such as radiology (Krupinski, 2010; Lesgold et al., 1988; Wood, 1999), programming (Sonnentag, Niessen, & Volmer, 2006), typing (Logan, Miller, & Strayer, 2011; Rieger, 2004, 2007; Salthouse, 1986), or fingerprint examination (Busey & Parada, 2010), in sports (for a short review see Williams, 2002) like basketball (Allard, Graham, & Paarsalu, 1980; Kunde, Skirde, & Weigelt, 2011; Oliveira, Oudejans, & Beck, 2009), football (Weigelt, Memmert, & Schack, sub.; Williams, Hodges, North, & Barton, 2006), karate (Mori, Ohtani, & Imanaka, 2002), or snooker (Abernethy, Neal, Koning, 1994), in action video games (Green & Bavelier, 2003), in dynamic environments (Collier, Eyrolle, & Marinè, 1997), or board games (Gobet, de Voogt, & Retschitzki, 2004), especially such as chess (de Groot, 1946/1978; Chase & Simon, 1973; for a review see Gobet & Charness, 2006) or go (Reitmann, 1976).

Therefore in the following, three domains of expertise, that illustrate the interaction of knowledge and perception, are described exemplarily: playing action video game, radiology, and the game of chess.

2.1.1. Generality of (perceptual) expertise: Playing action video games

One domain of expertise that has found increased interest and distribution over the last three decades is playing video games. Whereas public and also scientific interest has focused mainly on the impact of violent video game exposure on behaviour (e.g. Carnagey, Anderson, & Bushman, 2007) and on the epidemiology as well as on the appropriate treatment of video game addiction (e.g. Griffiths & Meredith, 2009), there are new findings revealing an astonishing improvement on vision, perceptual attention and cognitive control as a result of playing action video games.

In a seminal series of experiments, Green and Bavelier (2003, 2006a, 2006b, 2007; see Green, Li, & Bavelier, 2010, for a review) compared casual action video game players and novices in a selection of standard paradigms of cognitive psychology: flanker task, enumeration task, useful field of view task, attentional blink task, multiple object tracking task, perceptual load paradigm, and crowding paradigm. In contrast to novices, action video game players showed superiority in both peripheral and central vision. They performed better under dual task conditions and possessed a greater attention capacity, an enhanced spatial distribution of attention, a higher temporal and spatial resolution, and enhanced attentional resources. Action video game usage also seems to promote parallel processing, as action video game players were able to enumerate and track substantially more items at once than novices (Green & Bavelier, 2006b; see also Trick, Jaspers-Fayer, & Sethi, 2005). Moreover, the results of most of these experiments could be replicated in subsequent training studies (e.g. Green & Bavelier, 2003, 2006a, 2006b, 2007) where novices who were trained with an action video game (Medal of Honor, Call of Duty 2, or Unreal Tournament) performed better than novices who were trained with a non-action video game (Tetris or The Sims). Between 10 and 50 hours of training with an action video game were already sufficient to induce considerable improvements. This rules out that confounding pre-experimental differences between action video game players and novices like population bias contaminated the results and establishes a causal link between action video game usage and the observed enhancements.

Following the same line, Li, Polat, Makous, and Bavelier (2009) reported a long-lasting enhancement of contrast sensitivity through action video game playing and intensive training. Contrast sensitivity is “the ability to detect small increments in shades of grey on a uniform background” (Li et al., 2009, p. 549). It is seen as “one of the most basic visual functions that commonly deteriorate with aging” (Caplovitz & Kastner, 2009, p. 527) and held to be important in many different visual tasks. Contrast sensitivity was measured with a detection task for a briefly presented gabor patch. Detection performance was better for action video game players and action video game trained participants than for novices and non-action video game trained participants, which was explained as an increase in neural plasticity as a result of action video game exposure.

Furthermore, a meta-analysis that included seven studies with a total of nine experiments revealed that action video game players responded faster than novice video game players in several different experimental tasks like spatial cuing, Simon task, or inhibition of return (Dye, Green, & Bavelier, 2009). Importantly, this accelerated processing was not adulterated by a speed-accuracy trade-off, as overall error rates for experts and novices were equal.

Recently, Colzato, van Leeuwen, van den Wildenberg, and Hommel (2010) found that video game experience is also associated with an increased ability to switch between two tasks. In a task switching experiment, instructions were given trial by trial to respond either to the global or the local shape of a target object. Switch costs in RTs that typically arise when switching from one task to the other were reduced for participants who mainly played ego shooters, whereas no general effect on visual attention was found. Reviews about task switching (Kiesel, et al., 2010; Monsell, 2003) and a study examining individual differences in executive functions (Miyake, et al., 2000) underline that the task switching paradigm provides a good measure for mental flexibility and cognitive control. Therefore, Colzato and her colleagues concluded that “rather than low-level perceptual or vision-related attentional processes per se, it might be executive control functions that are improved by videogame practice” (Colzato et al., 2010, p. 10).

The results of these studies about action video game expertise are remarkable not only because they appear to indicate the opposite of commonly feared side effects of (action) video game consumption, such as deterioration in vision. Much more interestingly, these studies show that the effects of expertise, i.e. improvement of executive functions as well as perceptual learning, can generalize to new tasks and over the domain of the original expertise. For example, action video game players also showed benefits for multisensory processing when visual and auditory stimuli were presented in close temporal succession (Donohue, Woldorff, & Mitroff, 2010). Interestingly, as the training experiments with non-action video games, which did not result in improvements, revealed, there are some specific properties of video games needed in order for the observed transfer of visual expertise to occur, e.g. carrying out precise movements under visual guidance, observing simultaneously mutiple targets, and reacting to rapid-moving stimuli that often appear suddenly and unpredictable. Nevertheless, a large variety of action video games was found to enhance a wide range of cognitive and perceptual skills. Both strategic (e.g. enhanced visual working memory, cf. Green & Bavelier, 2006b) and fundamental changes in vision (e.g. enhanced contrast sensitivity, cf. Li et al., 2009) are held responsible for these improvements.

2.1.2. Natural expertise: Radiology

When looking at an X-ray image, which is frequently of low resolution and depicts obscure inner regions of the body, laymen sometimes feel similar like the Yanomami from the Amazon rainforest in front of a mobile phone. Referring to such a special domain, it is obvious that (physiological as well as pathological) knowledge shapes vision of, and perception with, the object of expertise in a fundamental way. Analyzing radiological images is a very complex and highly demanding task. Thus, the ability to deduce information from X-ray images is acquired over years through continuous job experience and systematic training. In Germany for example, it takes at least five years for a medical resident to become specialized as a radiologist. On that way, thousands of different radiologic patterns that finally have become organized in a “searchable mental matrix of diagnostic meaning and pathologic features” (Wood, 1999, p. 1) have been processed. Lesgold and colleagues (1988) calculated the number of cases in which radiologists (with up to 10 and more years of experience) in their study analysed x-ray images and came to the considerable number of 10,000 to 200,000 trials. Making the right diagnosis on the basis of X-ray images is essential to a suitable treatment of many different injuries and diseases. And in case of emergency, it is necessary to analyse X-ray images and draw conclusions in a very short time, in order to find the source of life-threatening inner injuries and enable diagnosis early enough for an adequate therapy.

In contrast to novices, expert radiologists process x-ray images faster as well as in more detail, they are able to connect their findings to other findings more frequently, they can better recognize previously seen images with abnormalities, and they make more often the correct diagnoses (Christensen et al., 1981, Lesgold, et al., 1988; Myles-Worsely, Johnston, & Simons, 1988; Wood, 1999).

Astonishingly, for X-ray experts a single glance at a pathological image is often sufficient to correctly diagnose a disease. Although radiologists performed much better when viewing time for chest films of major abnormalities was not limited, they still made 70% true positive decisions (the mean d'-score was over 1.0 and differed significantly from zero) when presentation time was reduced to just 200 ms (Kundel & Nodine, 1975; see also Christensen, et al., 1981). During that short time no saccades can be made, whereas with a single fixation, shifts of attention are possible. Therefore, an initial global response, active visual search, and peripheral vision were seen responsible for this remarkable and almost immediate detection accuracy of X-ray experts.

Yet, between X-ray experts and novices not only quantitative but also qualitative differences exists, whereas the latter is probably essential for the superior performance of expert radiologists. Contrary to (action) video game expertise, X-ray expertise is not accompanied by a better visual acuity, because experts' superiority is lost in comparable visual domains outside the field of expertise (Chi, 2006a; however see Snowden, Davies, & Roling, 2000, who assume that X-ray expertise is indeed associated to an enhanced visual sensitivity). Hence, Chi stated tellingly that X-ray "expertise involves perceiving more, not just seeing more" (2006a, p. 174), while seeing was defined as "literal stimulus features" and perceiving as "meanings of the features or patterns of features" (2006a, p. 172).

Likewise, Lesgold and colleagues (1988) were interested to find out what radiologists are exactly doing when they examine an X-Ray image. In two experiments including also some more naturalistic tasks and observations, they compared participants whose experience in radiology differed systematically (residents in their first to fourth year and experts with at least over ten years practise after residency). The experts were not only more correct in their diagnoses for diseases (e.g. atelectasis or tumor) according to abnormalities in chest films presented among normal chest films than the residents, but had also a higher number of findings of aberrations, their causes, as well as their effects, their protocols included longer chains of reasoning, and they connected their findings more often to other findings. Interestingly, although the same film was presented to all subjects, such a large variety of different observations was given, that it appeared that almost completely different things were perceived. In order to find out how these different individual perceptions influenced the diagnostic decision, subjects were asked to draw contours around critical observations. It became evident that almost all subjects saw the main features as for example a collapsed lung. However, the residents were less likely to detect local as well as global cues that are decisive for the interpretations of the findings. Instead they were more reluctant to refute an inappropriate schema (i.e. a mental representation of anatomical structures) and often ignored inconsistent findings, i.e. signs of pathological changes, when the scheme for a normal chest was applied. Experts, on the other hand, were more sensible for subtle cues, made finer discriminations, and perceived more peripheral features. Almost instantly they evoked an appropriate schema, but they were also much more flexible in their diagnostic decisions and dealing with the schema when new information had to be considered. Moreover, expert radiologists seemed to be able to tune their feature perceptions specifically to the current case and knew where to look at in the film. Comparing with eyetracking devices, where exactly radiology novices and experts looked at a medical image, confirms the latter. Experts made more fixations at diagnostically relevant areas with abnormalities (cf. Kundel & Nodine, 1975) and looked less often at unimportant regions than residents or students (Krupinski et al., 2006).

However, X-ray expertise can also be a two-edged sword insofar as an increased recognition performance for abnormal X-ray images appears to be related to a decreased recognition memory for normal X-ray images (Myles-Worsely et al., 1988). Four groups of participants who possessed varying degrees of X-ray expertise, ranging from novices to senior radiologists with a mean of 22 years of radiological experience were compared in a memory task using new and old pictures that had been presented 500 ms in advance. No group differences and no best memory performance were found for faces, for which it can be assumed that all participants had an equal amount of experience. Memory for X-ray films showing abnormal images was best for senior scientists whose results did not differ from the others' in memory of faces. However, for normal X-ray images, recognition performance decreased with increasing expertise and even reached change level for the senior radiologists. Presumably, enhanced searching for pathological abnormalities diminishes the change to detect normal abbreviations (for expertise specific performance losses in another visual domains, see for example Bialic, McLeod, & Gobet, 2008 for chess experts or McKeeff, McGugin, Tong, & Gauthier, 2010 for car experts).

To sum up, X-ray experts differ from novices in quantitative as well as in qualitative aspects. Thus, X-ray experts do not only perform better in related tasks, they also “see things differently” (p. 329, Lesgold et al., 1988). Radiology expertise seems to be a rather specific form of perceptual expertise, because experts' superiority is constricted mainly to the analysis of medical images and can even come along with a reduced ability to recognize normal x-ray images.

2.1.3. Drosophila of psychology: Chess expertise

Studies with the game of chess have a pivotal role – not only in expertise research (e.g. Ericsson & Lehmann, 1996; Gobet & Charness, 2006; Schneider, 2000) but also generally in psychology. Simon and Chase (1973) proposed that similar to the importance of the fruit fly Drosophila as a model organism for genetic studies, chess provides ideal task environments for psychology research. Therefore, chess studies have given useful insights in developmental issues (Chi, 1978; Grabner, Stern, & Neubaur, 2007; Opwis, Gold, Gruber, & Schneider, 1990; Schneider, Gruber, Gold, & Opwis, 1993), neuroscience (Amidzic, Riehle, Fehr, Wienbruch, & Elbert, 2001; Atherton, Zhuang, Bart, Hu, & He, 2003; Bilalić, Langer, Erb, & Grodd, 2010; Campitelli, Gobet, Head, Buckley, & Parker, 2007; Nichelli et al, 1994; Onofrj, et al., 1995), and cognitive science (Charness, 1992; Gobet et al., 2004; Newell & Simon, 1972; van der Maas & Wagenmakers, 2005).

Hence, the game of chess has frequently been used to examine higher-order cognitions such as problem solving (Bilalic et al., 2008; Bilalić, McLeod, & Gobet, 2009; Gobet & Charness, 2006; Saariluoma, 1985) or knowledge acquisition and storage (Charness, 1991; Ericsson & Kintsch, 1995; Freyhof, Gruber, & Ziegler, 1992; Gobet, 1998, Gobet & Waters, 2003), as well as to trace the development of human intelligence (Gobet, Campitelli, & Waters, 2002; Howard, 1999).

Chess masters are able to do amazing feats: In a very complex environment with a real jungle of possibilities, they nevertheless find usually the best move

(Bilalić, et al., 2010). They regularly win against dozens of weaker players at the same time, even without seeing the chess board (Gobet, Chassy, & Bilalić, 2011), whereas the world record in so-called simultaneous blindfold chess play is held with over 30 simultaneous played chess games (“Melody amber”, 2003). However, how to become a chess master?

On the one hand, there is evidence that individual differences or innate factors such as talent influence the development of chess expertise. Chess skill, for example, correlates with intelligence – especially with numerical intelligence (Grabner, Neubauer, & Stern, 2006; Grabner et al., 2007; Horgan & Morgan, 1990; however see Bilalić, McLeod, & Gobet, 2007, as well as Gobet et al., 2002, for a critical view). On the other hand, it has been shown that experience (Bilalić et al., 2007; Grabner et al., 2007), i.e. deliberate practice (Ericsson, 2006; Ericsson, Krampe, & Tesch-Römer, 1993) is the decisive factor in the development of chess expertise, so that “individuals attain internationally recognized levels of exceptional performance only after spending about 10 years in intense preparation” (Ericsson & Lehmann, 1996, p. 296). Simon and Chase (1973) already suggested that it will take at least 9 to 10 years for a chess player to become grandmaster. Although nowadays, the youngest grandmaster in chess history, Sergey Karjakin learned to play chess when he was five years old and scored the last grandmaster norm already with the age of 12.7 years, apart from few chess prodigies such as Karjakin, the 10-year rule is still valid for the majority of chess grandmasters (cf. Ericsson & Ward, 2007).

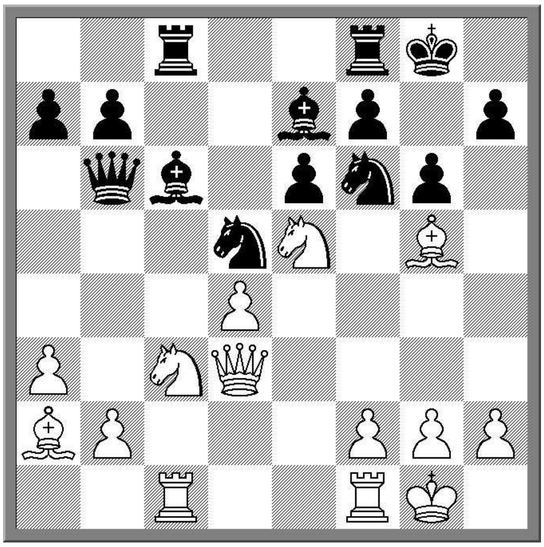

Figure 2. A middlegame position from a chess game between A.D. de Groot and C. Scholtens, 1936, White to move (Adapted from de Groot, 1978, p. 89).

The nature of X-ray expertise is often compared with expertise in the game of chess (for a review see Reingold & Sheridan, in press). Parallels between X-ray and chess expertise are seen concerning the extraction of relevant information (Wood, 1999), decision making (Ericsson & Ward, 2007), the accumulation of integrated representations (Raufaste, Eyrolle, & Mariné, 1998), the storage of meaningful patterns in memory (Wood, 1999), and above all in the general observation that experts perceive things fundamentally different than novices (Chi, 2006a). For example, when looking at a chess diagram like the one depicted in Figure 2 (white to move, adapted from de Groot, 1978), what one can see highly depends on the knowledge about chess. So, one might see a (known) middle game position, strategic options, attacking possibilities (especially the opportunity for white to win a piece), or only black and white pieces on a chess board.

Over 60 years ago, Adriaan D. de Groot, a Dutch chess master and psychologist wanted to find out what processes in the chess players mind are underlying the choice of a move. In a classical study de Groot (1946, 1978), asked chess players to think aloud while they searched for the best move in a chess position from an actual tournament or match game, but unknown to them. Contrary to what was originally expected, verbal protocols revealed that, although grandmasters “who can be considered as super-experts” (Gobet et al., 2011, p. 227) find better moves, they did not calculate more moves than chess experts. De Groot assumed that differences in how the chess positions are perceived are crucial for the superiority of the masters and therefore conducted a second experiment to investigate the influence of memory and perception on chess (cf. Gobet, 2006). He found that chess masters have the astonishing ability to reconstruct the locations of chess pieces from a game position almost perfectly, even if the chessboard was only briefly presented (2-15 sec), while weaker players could recall only a few pieces.

Chase and Simon (1973a, 1973b) replicated and extended these results. They showed that chess experts are much better than less skilled chess players in this reconstruction/recall task, but only when a game position was presented. The advantage of the experts almost vanished when random positions were used. Based on these results, Chase and Simon (1973a, 1973b) assumed that after playing chess for years, experts have acquired thousands of chunks for meaningful relations of chess pieces, like for example the position of pawns, king and rook after castling king's side (depicted with the white pieces in Figure 2). Based on a computer simulation of an information-processing model, Simon and Gilmartin (1973) calculated that chess masters possess indeed between 10.000 and 100.000 chunks. Chase and Simon (1973a, 1973b) referred to Miller's fundamental work on the limit of the short-term memory (Miller, 1956) and pointed out that chess experts' memory span is also restricted to capacity of seven plus or minus two elements. However, for experts, an element consists of a chunk of three to five chess pieces, whereas for novices an element consists only of a single piece. These perceptual chunks are further integrated into larger long-term memory structures called templates. The templates include the positions of 10 or 12 pieces and slots for variable information (for the original chunking theory see Chase & Simon, 1973a, 1973b; for the template theory see Gobet & Simon, 1996a; 2000a; but see Ericsson & Kintsch, 1995, for an alternative long-term working memory theory). Taking the availability of templates into account, Gobet and Simon (2000a) modelled the recall performance of chess players. For a master, the discrimination net comprised 300.000 chunks, whereas an expert player and a class A player, come with 10.000 and 5.000 chunks, respectively. The finding that better players have much more chunks and templates encoded in long-term memory than weaker players (Amidzic et al., 2001) is also seen as the main reason for skill differences in chess (Chase & Simon, 1973a, 1973b; Gobet et al., 2001; Gobet et al., 2011;

but see Holding, 1985, 1992, who suggests that thinking ahead is more important than pattern recognition).

Additional support for the notion that chess expertise relies more on fast mechanisms such as recognition (of chunks and templates) than on slow mechanisms such as search (for further moves and possible replies) comes from studies where chess player's performance of blitz and normal chess games is compared (Burns 2004; Calderwood, Klein, & Crandall, 1988; Gobet & Simon, 1996b). In normal games every player has at least 2 h for the first forty moves so that there is enough time for search, whereas in blitz chess every player has only 5 minutes for the whole game so that search time is restricted. Nevertheless, Burns (2004) found a very high correlation between performance in blitz and performance in nonblitz chess games, indicating that chess skill is mainly based on fast processes such as pattern recognition. Following the same line, Gobet and Simon (1996b, for a discussion see Lassiter, 2000 and Gobet & Simon, 2000b) reported that the performance of the former world champion Gary Kasparov was only slightly reduced when he played simultaneously and therefore with only a forth or eighth of the normal time available. Thus, in virtue of the availability of chunks and templates, chess experts have acquired schemas that guide their search for, i.e. their recognition of, the best move in a new chess situation (Gobet et al., 2011).

In contrast to the general improvements through playing action video games, chess experts' advantages are rather domain-specific. Thus, the effects of chess expertise completely vanished or are at least sharply diminished when random chess positions (Chase and Simon, 1973a, 1973b; Gobet & Simon, 1996a, 1996b, 2000a), unfamiliar material such as letters (Reingold, Charness, Pomplun, & Stampe, 2001) or wooden pieces (Opwis et al., 1990; Schneider et al., 1993) were used instead of chess diagrams or chess pieces. Moreover, children chess experts performed better than adult novices in a recognition task for chess positions, while they performed worse in a digit span memory task (Chi, 1978), showing that the usual superiority of adults' short-term memory capacity (Schneider et al., 1993) was still present when the child experts could not rely on domain-specific knowledge. Gobet and Campitelli (2006) critically reviewed the limited number of scientific studies that explored whether chess skills can transfer to general abilities. In contrast to all the benefits of chess instruction that chess organisations propose, Gobet and Campitelli found indeed weak evidence for an improvement of verbal ability and school results, but no evidence for an increase in intelligence, visuo-spatial abilities, or other cognitive skills through chess practise.

De Groot and Gobet (1996) examined what chess players are exactly locking at, when they process a chess position. Eye-movement recordings revealed that in contrast to weaker chess players, more experienced chess players fixated more often on the edges of the squares, had shorter fixation durations and had greater distances between the single fixations, while they had to memorize new a chess position. Theses results imply that more experienced chess players are able to encode faster and larger areas of a chessboard than weaker players (Gobet & Charness, 2006).

Within the same line of reasoning, there is new evidence for task-specific perceptual encoding advantages in the game of chess. For example, Reingold, Charness, Pomplun, and Stampe (2001) also observed that skilled chess players encode larger portions of structured chess positions during each fixation than chess novices. However, experts lost their encoding advantage when random positions were used. Moreover, Reingold, Charness, Schultetus, and Stampe (2001) demonstrated that experts encode chess relations automatically and in parallel. They applied a check detection task on a five-by-five square segment of a chessboard. Participants were asked to indicate whether a cued attacker checks the king. In addition, a second attacker was presented which was not relevant for the instructed task. Nevertheless, this distractor check piece was processed because responding was slower when the second attacker was incongruent (i.e. was checking while the cued attacker was nonchecking) rather than congruent to the cued one, reflecting a Stroop-like interference effect. These and similar findings led to the conclusion that perceptual superiority is a fundamental component of chess expertise (e.g., Charness, Reingold, Pomplun, & Stampe, 2001; de Groot & Gobet, 1996; Saariluoma, 1985; for an overview see Gobet & Charness, 2006).

3. Subliminal perception in chess

Experiment 1-3 were designed to explore expertise-based perceptual improvements[3]. I tested whether expertise in chess can enable cognitive processes that are normally linked to conscious experience and to run outside of awareness. To investigate processing outside of awareness a subliminal response priming task was applied (see chapter 1).

Specifically, I wanted to find out if chess experts are able to recognize rapidly, and entirely unconsciously, whether a briefly presented chess situation entails a checking configuration. Such a finding would be important in two respects. First, research on unconscious response priming suggests that beyond simple perceptual classifications (Neumann & Klotz, 1994; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003) several cognitive processes can be applied to subliminal stimuli as well. Recent examples include the judgment of numerical size of numbers (Dehaene et al., 1998), the classification of letters as vowels and consonants (Kiesel et al., 2007b; Reynvoet et al., 2005), the evaluation of words as positive or negative (Klauer et al., 2007) or as denoting small or large objects (Kiesel, Kunde, et al., 2006). The necessary operations to solve these tasks can be construed as being well-trained (either explicitly as in counting or implicitly as in reading) suggesting that practice might be an important prerequisite of subliminal processing (e.g. in the case of reading letters are automatically integrated and form

[3] Parts of this section (considering Experiment 1 and 2) are already published in Kiesel, Kunde, Pohl, Berner, & Hoffmann, 2009

word “chunks”). Yet, to the best of my knowledge this conjecture has never been tested directly. Demonstrating differential effects of subliminal stimuli for participants who do or do not posses high amounts of practice with a certain stimulus domain would strongly support the view that practice is a crucial determinant of unconscious processing.

Second, the specific example investigated here would be remarkable because the evaluation of a checking configuration requires solving an XOR-task (a detailed description of the task is given below) and therefore requires conjointly combining two stimulus features, such as the form of the chess pieces and their spatial location in relation to the king. Such feature integration has been assumed to require attention (Treisman, 1996). Moreover, theoretical work by Engel and Singer (2001) as well as empirical work by Tapia and Breitmeyer (2006) previously suggested that feature integration is confined to consciously identified stimuli. From a neurophysiologic perspective, feature integration is required when different features are processed and represented in different neuronal assemblies. Feature binding is assumed to be due to temporal (gamma) synchronization of neuronal activity. Recently, Engel and Singer (2001) considered gamma synchronizations as the neuronal correlate for conscious representation. Consequently, feature binding has been assumed to be confined to consciously presented stimuli. However, demonstrating unconscious check detection would challenge this view, or would at least call for an explanation without assuming feature integration. I will come back to this issue in Experiment 2.

3.1. Experiment 1: Comparison of experts and novices with a subliminal check detection task

The performance of chess experts and chess novices was compared in a subliminal priming task illustrated in Figure 3. Stimuli were 3x3 chessboards which either diagrammed a checking or a nonchecking configuration. The king was always presented in the upper left corner and the attacker was either rook or knight. Participants carried out one response upon identifying a checking position and another response upon identifying a nonchecking configuration (for similar check detection tasks see (Bilalić, Kiesel, Pohl, Erb, & Grodd, 2011; Reingold, Charness, Pomplun, & Stampe, 2001; Saariluoma, 1985). For example, a rook presented in the upper right corner represents a checking configuration (see Figure 3, Panel A) whereas a knight presented in the upper right corner represents a nonchecking configuration (Panel B). In contrast, a rook presented in the lower middle square represents a nonchecking configuration (Panel D) whereas a knight presented in the lower middle square (Panel C) represents a checking configuration. Thus, the applied check detection task constitutes an XOR problem because two diagrams require the same response (i.e. are congruent) either when both features, form and location in relation to the king, are the same or both differ (e.g. Panel A and Panel C) - whereas two diagrams require different responses (i.e. are incongruent) if one feature is repeated while the other changes (e.g. Panel A and Panel B). Before each target configuration, a prime configuration was shown briefly and masked immediately, so that participants were unable to consciously perceive the prime configurations. The accurate processing of the unconscious configuration would be indicated by a response priming effect, i.e. faster responses when both, prime and target, configurations were checking or both were nonchecking (congruent trials) than when one configuration was checking but the other was not (incongruent trials).

In addition, half of the prime configurations were never used as target stimuli, that is, participants never categorized them consciously. These novel primes were included to rule out that response priming resulted merely from acquired stimulus-response links which evolve in the course of the experiment when participants repeatedly respond to the consciously seen targets (Abrams, 2008b; Abrams & Greenwald, 2000; Damian, 2001).

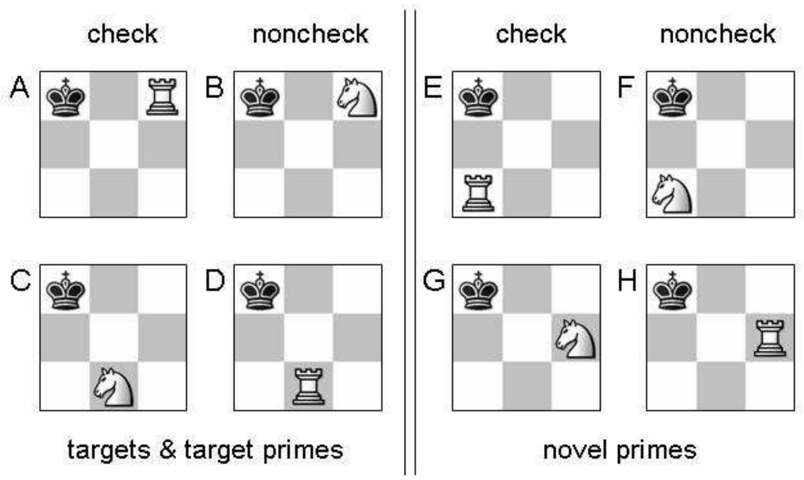

Figure 3. Stimulus material used for targets and target primes in Experiment 1: The 3 x 3 grids either displayed a checking configuration (panels A, C, E, and G) or a nonchecking configuration (panels B, D, F, and H). The 3 x 3 grids were either presented as targets as well as primes (panels A, B, C, and D) or only as primes (panels E, F, G, and H).

Concerning possible results, experts and novices may differ in several aspects. First, the amount of response priming might be larger for experts than for novices. Second, experts may be the only who will show priming effects for novel primes. Third, only experts may reveal priming effects while it is possible that novices do not show any priming even for target primes.

Moreover, I will also consider the impact of perceptual priming in this paradigm. In this context perceptual priming can occur in the following two regards: On the one hand, the attacker in the prime and target diagram can occur on the same or different location (location priming). On the other hand, the identity of the attacker in prime and target diagram can be the same or different (form priming). In addition to response priming I will elaborate whether these more low level priming effects impact on behaviour.

3.1.1. Method

(1) Participants

12 chess players (aged 18-50; DWZ[4] scores 1346-2150, M = 1746[5], SD = 215) and 24 chess novices (aged 20-45; inexperienced chess players who

[4] DWZ is the abbreviation for “Deutsche Wertungszahl,” which is the rating of the German chess federation; the rating roughly matches ELO ratings.

[5] According to their playing strength and ranking chess players in our study are so-called class D, class C, class B, class A players, or experts but no national masters, candidate masters or masters (e.g. Glenz, 1997).Thus, most of the chess players that participated in Experiment 1-3 would be categorized as intermediate players in chess ranking. Nevertheless, the term experts was used for them to contrast their experience with the novices in this study.

reported having played no more than 100 games) participated each in an individual session of approximately 55 min. All participants declared having normal or corrected-to-normal vision and were not familiar with the purpose of the experiment.

(2) Apparatus and stimuli

An IBM-compatible computer with a 17 inch VGA-Diagram (vertical retraces 100 Hz) and an external keyboard was used for stimulus presentation and response sampling.

Stimuli were eight pictures of minimized 3x3 chessboards extending 45 x 45 mm. The king was always located in the upper left corner. The attacker, either rook or knight, was located in one of four positions (upper right, middle right, lower left, and lower middle square). Four of the chessboards (rook or knight located in the upper right or lower middle square) served as targets. All eight chessboards were used as primes, enabling to compare the effects of novel and target primes. Masks were random dot patterns extending 80 x 80 mm.

(3) Design and procedere

Each trial started with an empty 3x3 grid with a fixation cross in the middle presented for 400 ms. Then, premask, prime, postmask, and target were presented. To enhance masking, premask and postmask each consisted of 3 different random dot patterns presented for 30, 20, and 20 ms. Prime duration was

20 ms, target duration was 250 ms (the sequence of the events is depicted in Figure 4).

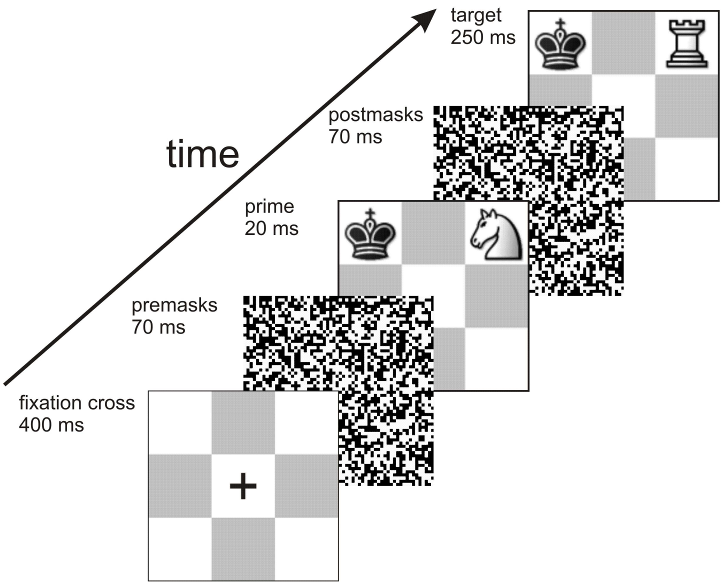

Figure 4. Experimental procedure in Experiment 1: On each trial, fixation cross, premasks, prime, postmasks, and target were presented. Participants indicated whether the target displayed a checking or a nonchecking configuration. In half of the trials, the prime was response congruent (prime and target would require the same responses). Primes were either also presented as targets (target primes) or they were novel stimuli (novel primes). The sequence of events shows a response incongruent trial, because the prime diagram (knight located on the upper right square) would afford the response indicating "no check" while the target diagram (rook located on the upper right square) affords the alternative response indicating "check". Concerning perceptual priming this trial is location congruent (both knight and rook are located on the same square) and form incongruent (a knight is presented in the prime diagram whereas a rook is presented in the target diagram).

Participants were instructed to indicate whether the target diagrammed a checking or a nonchecking configuration by pressing a left or right key. Errors and missing responses (exceeding 5 sec after target onset) were fed back.

The experiment consisted of 10 blocks in each of which each combination of prime (8) x target (4) was presented twice in random order. It finished with a detection task to test participants' awareness of the primes. Participants were fully informed about the structure of the prime stimuli and were then presented with 128 identical trials for which they were to discriminate whether the prime diagrammed a checking or a nonchecking configuration.

3.1.2. Results

(1) Response Priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.1%) were excluded. Mean RTs for correct responses and error rates for each combination of the factors prime congruency and prime type for experts and novices are given in Table 1 (left columns).

An ANOVA on RTs for correct responses with the between subject factor expertise and with the within subject factors prime congruency and prime type revealed significant main effects for expertise, $F(1, 34) = 9.3$, $p < .01$, $\eta_p^2 = .21$, and prime congruency, $F(1, 34) = 8.4$, $p < .01$, $\eta_p^2 = .20$; as well as a significant interaction between expertise and prime congruency, $F(1, 34) = 10.5$, $p < .01$, $\eta_p^2 = .24$. The same ANOVA on error rates revealed no significant effects, *p*s > .17.

A separate ANOVA on RTs revealed that chess experts responded 11 ms faster with congruent compared to incongruent primes, $F(1, 11) = 17.7$, $p < .01$, η_p^2

= .62. Neither the main effect of prime type nor the interaction between both factors was significant, *p*s > .21. For chess novices the same ANOVAs on RTs revealed no significant effects, *p*s > .47.

Table 1. *Mean RTs for congruent and incongruent primes and the resulting response congruency effects (in ms) for target and novel primes in Experiment 1.*

	Experts		Novices	
	Target Primes	Novel Primes	Target Primes	Novel Primes
Incongruent Prime	536	534	624	627
Congruent Prime	521	526	626	627
Congruency Effect	14**	8*	-1	0

Note. Asterisks indicate significance level: ** p < .01; * p < .05 (one-tailed), discrepancies in the computed congruency effect result from rounding errors

On average chess players responded much faster than chess novices (529 ms vs. 626 ms) replicating previous findings by Jastrzembski, Charness, and Vasyukova (2006), Reingold, Charness, Pomplun, and Stampe (2001), and Saariluoma (1985), showing that skilled chess players are faster in a check detection task than novices. Thus, one might suspect that there was no congruency effect for chess novices because the prime-induced activation had already faded. To rule out this suspicion, the RT distributions were examined based on percentile values obtained for each participant (I chose percentiles of

5%, 15%, …, 95%). If prime-induced activation had faded for longer RTs, I would expect no congruency effect for higher percentiles in the experts data whereas for novices a congruency effect should turn up in the lower percentiles. This is clearly not the case (see Figure 5).

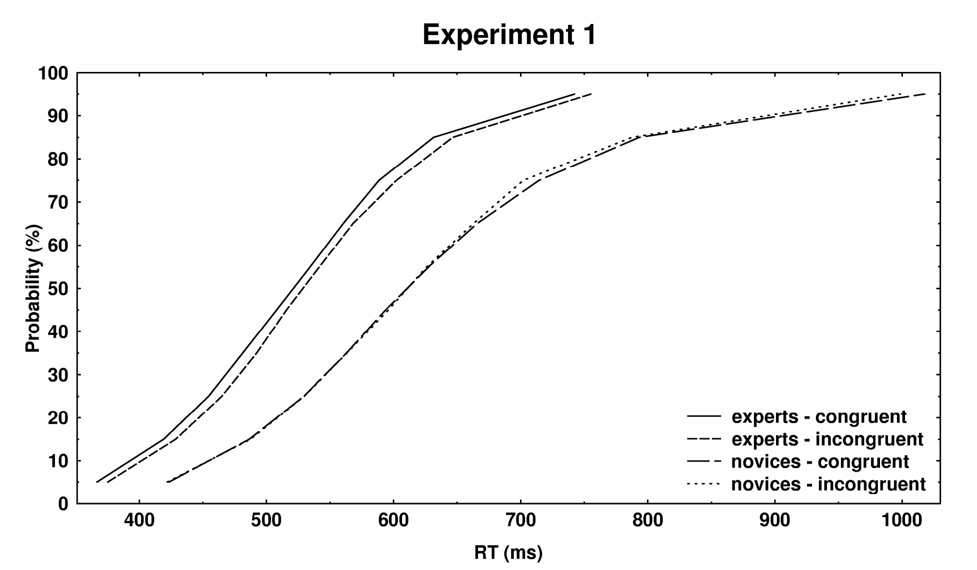

Figure 5. RT distributions depending on Congruency for Experiment 1. Chess experts performing a check detection task revealed significant response congruency effects over all percentiles except the last one (i.e. 95% percentile). Novices did not reveal response congruency effects at any percentile.

(2) Perceptual priming

In order to find out whether the accordance of perceptual features in the prime and target diagram influenced responding to the target, I looked additionally for perceptual priming effects. For the analysis of perceptual priming effects, target primes (for location and form effects) and novel primes (for form effects) were analyzed separately.

Target primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.0 %) were excluded. An ANOVA on RTs for correct responses to target primes with the between subject factor expertise (experts and novices) and with the within subject factors location congruency (incongruent and congruent) and form congruency (incongruent and congruent) revealed a significant 2-way interaction between location congruency and form congruency , $F(1, 34) = 6.3$, $p < .05$, $\eta_p^2 = .16$, as well as a significant 3-way interaction between expertise, location congruency, and form congruency, $F(1, 34) = 12.8$, $p < .01$, $\eta_p^2 = .27$. Neither the other 2-way interaction nor one of the single factors reached significance, *ps* > .10. The same ANOVA on error rates revealed only for the 2-way interaction between expertise and form congruency a significant effect, $F(1, 34) = 5.2$, $p < .05$, $\eta_p^2 = .13$, the other interactions and the single factors were not significant, *p*s > .20.

A separate ANOVA on RTs analyzing the data only for expert chess players (see Figure 6, left side) revealed no significant main effect for location congruency, $F(1, 11) = .1$, $p = .77$, $\eta_p^2 = .09$, a significant main effect for form congruency, $F(1, 11) = 7.4$, $p < .05$, $\eta_p^2 = .40$, as well as a significant interaction between location congruency and form congruency, $F(1, 11) = 21.9$, $p < .001$, $\eta_p^2 = .67$. The same ANOVA on error rates revealed no significant effects, $p > .12$. As the interaction for RTs is disordinal, I cannot interpret the main effect of form congruency, because form congruency only facilitated responses when the location of the attacker in prime and target diagram was congruent. However, when the location of the attacker in prime and target diagram was incongruent, then form congruency was associated with slower responses.

The same ANOVA on RTs analyzing the data for novices (see Figure 6, right side) revealed a marginally significant main effect for location congruency, $F(1, 23) = 3.0$, $p < .10$, $\eta_p^2 = .12$, but no significant effect for form congruency, $F(1, 23) = .8$, $p = .38$, $\eta_p^2 = .03$, as well as no significant interaction between location congruency and form congruency, $F(1, 23) = .7$, $p = .40$, $\eta_p^2 = .03$. Novices tended to responded faster when the location of the attacker was the same in prime and target diagram (631 ms different location vs. 620 ms same location). The same ANOVA on error rates revealed no significant effects, $p > .30$.

Inspection of Figure 6 illustrates the decisive difference concerning perceptual priming effects between experts and novices. For experts as well as novices fastest responses were observed when both perceptual features are congruent (also a response congruent case) as it can be seen on the white right bar. For experts however, second fastest responses emerged when both perceptual features were incongruent (that is also a response congruent case), as it can be seen on the black left bar. By contrast, novices descriptively produced slowest responses when both perceptual features were incongruent.

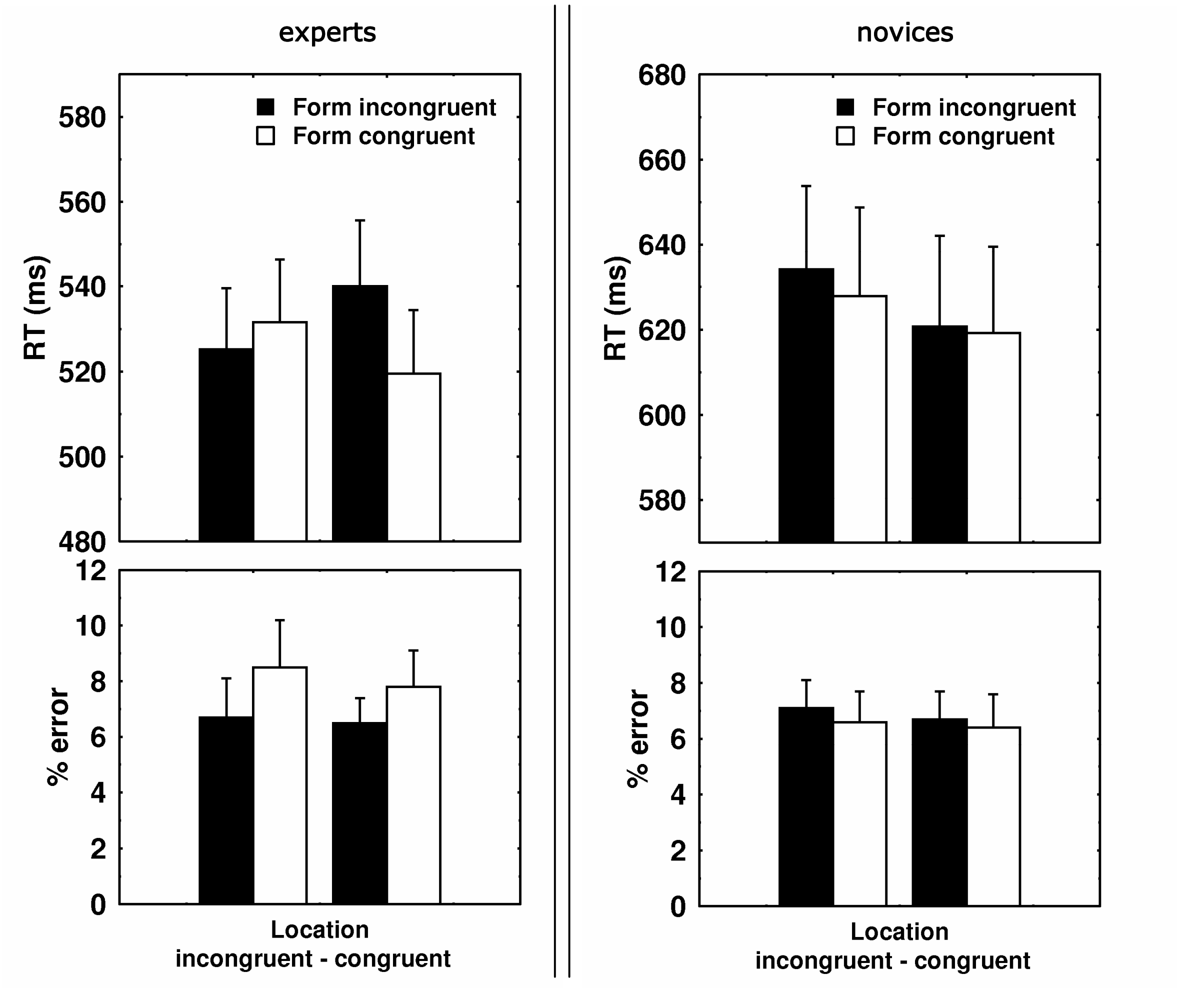

Figure 6. Experts (left) and novices (right) mean RTs (upper panel) and error rates (lower panel) for target primes depending on perceptual congruency (location and form) in Experiment 1. Lines represent standard errors.

Novel primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.0 %) were excluded. An ANOVA on RTs as well as on error rates for correct responses to novel primes with the between subject factor expertise and with the within subject factor form congruency revealed no significant effects, *p*s > .56.

(3) Prime visibility

Participants' discrimination performance for check vs. noncheck primes was $d' = .05$ for chess players and $d' = -.02$ for novices and did not deviate significantly from zero, *p*'s > .45.

To test whether the priming effect of the experts is related to individual prime visibility, a regression analysis as proposed by Draine and Greenwald (1998, see also Greenwald, Klinger, & Schuh, 1995; Greenwald, Draine, & Abrams, 1996) was computed. A priming index was calculated for each participant, with index = 100 x (RT incongruent – RT congruent) / RT congruent. Individual priming indices were regressed onto the individual d' values. The linear regression analysis revealed no significant correlation between d' and the priming index $r = .230$, $F(1, 11) = .56$, $p > .47$, whereas the intercept of the regression was larger than zero (intercept = 2.18, $t(11) = 4.41$, $p < .01$), indicating that significant priming effects are associated with d'-values of zero.

3.1.3. Discussion

Unconsciously presented chessboard configurations significantly influenced experts' check detection performance. Participants responded faster when both chessboards required the same compared to different responses. Even novel primes, that is, chess configurations that were never presented as targets in the experiment yielded response priming effects. This observation rules out that priming resulted from learned S-R links which were acquired in the course of the experiment because participants repeatedly performed the same response upon a target stimulus (e.g. Abrams, 2008b, Abrams & Greenwald, 2000; Damian, 2001). Instead, chess experts were able to rapidly judge chess configurations as checking or nonchecking even for unconsciously presented check configurations. In contrast, novices did not reveal a subliminal response priming effect, rather it seems to be, that for novices the congruence of the single perceptual features location and form was decisive for facilitation effects, i.e. perceptual priming. The possible influence of perceptual congruence (of the features location and form of the attacker) that is contrasted with response congruence will be examined more closely in Experiments 4-9.

In contrast to novices, experts revealed response priming for target primes as well as for novel primes. These results are in line with the account of activation of semantic response categories (e.g. Dehaene et al., 1998; Naccache & Dehaene, 2001; Reynvoet et al., 2002) because responses were faster, when the meaning of the chess diagrams presented as prime and target was the same, i.e. both check or no both no check, compared to trials were the meaning of prime and target chess diagram was different, i.e. check and no check or no check and check. One can assume that the semantic relations of similar chess information as well as the formation of distinct categories are much more pronounced in experts than in novices, which is responsible for the observed pattern of results.

Likewise, the account of programmed S-R links (e.g. Kunde et al., 2003; Kiesel et al., 2007b; Kiesel et al., 2006) may also help to explain why experts but not novices revealed response priming even for novel primes. It is conceivable that due to their comprehensive experience with chess situations, the experts were able to form specific expectations for the possible chess configurations which also comprised the diagrams presented as novel primes. In this regard, the comment of an expert player, who participated in Experiment 1, is interesting. After the instruction was administered, the expert player said spontaneously that with the given constraints there can't be many different chess diagrams. Thus, it seems to be that the chess expert had formed offline appropriate release conditions for the left and right response, respectively. Novices on the other hand, have only limited experience in the game of chess. They have to deal with lots of different and new information and are therefore unable to form action triggers.

Regarding the nature of the observed priming effect, that is, the question whether congruent primes facilitate responding and/or incongruent primes interfere with performing the alternative response, I can currently just speculate. Subliminal priming studies that used a baseline condition, observed facilitation as well as interference effects by congruent and incongruent primes, respectively (e.g. Neumann & Klotz, 1994). Electrophysiological as well as functional imaging studies (e.g., Dehaene et al., 1998; Eimer & Schlaghecken, 2003; Leuthold & Kopp, 1998) revealed that the subliminally presented prime triggers motor activation of the task-assigned response. In case of congruent primes, responding to the target is facilitated because the currently required response is pre-activated by the prime whereas in case of incongruent primes, the alternative response is pre-activated and interferes with response execution. Yet, for the applied check detection task, it is currently unclear whether the chess configurations presented as primes also trigger the task-assigned motor response. Alternatively, one might assume that the observed response priming effects are merely due to facilitation effects that take place on a more conceptual level.

Irrespective of the exact mechanisms underlying the observed response priming effects, these results are striking because check detection nominally requires conjointly considering the location and form of the attacker. If participants merely took into account one feature of the unconscious prime, that is, either location (e.g., the attacker is presented in the right upper corner, see Figure 3, Panel A and B) or form of the attacker (e.g., rook, see Panel A and D), primes could not be categorized as checking or nonchecking. Thus, apparently experts but not novices, show rapid integration of two stimulus features despite their having been presented unconsciously. This would mean that experts differ from novices fundamentally regarding the ability to integrate features of unconsciously presented stimuli.

Yet, there is another explanation which does not postulate such a fundamental difference of cognitive processing. Basically this account assumes that expertise allows experts to bypass cognitive operations by relying instead on memories of stored task solutions (Chase & Simon, 1973a, 1973b; Gobet & Simon, 1996b; 2000a; for a general theory of automaticity see Logan, 1988). This account holds that experts acquired perceptual chunks[6] for typical chess configurations

[6] The term *perceptual chunks* was used to stress the process of perceptual learning. Within this sense, perceptual chunks are photograph-like images of known objects stored in memory

during intensive training; most likely especially for most important configurations in which the king is immediately threatened by an attacker (e.g. Mc Gregor & Howes, 2002, for the importance of attack/defense relations). Conceivably, these perceptual chunks represent integrated memories in which the features of chess pieces' identities and their spatial relations are already bound together. To the extent that an encountered configuration matches a stored checking configuration the associated "checking" motor response is triggered (cf. Kunde et al., 2003).

If this second alternative holds true, chess experts should not reveal subliminal response priming effects, if the response decision does not rely on acquired perceptual chunks of chess configurations. This assumption was tested in Experiment 2.

3.2. Experiment 2: XOR-task for chess experts

The same 3x3 grids as in Experiment 1 were used. However, instead of a checking or nonchecking configuration, only one single chess piece, either rook or knight, was presented. Participants were instructed to press one response key, if the rook was presented on a white field (see Figure 7, Panel A) or the knight was presented on a black field (Panel C) and the alternative response key, if the rook was presented on a black field (Panel D) or the knight was presented on a white field (Panel B). Again a masked prime appeared prior to each target which either required the same (congruent trials) or the alternative response (incongruent trials)

(Goldstone, 1998). This meaning is equivalent to the use of the term perceptual chunks in the chunking theory and the template theory in the field of chess expertise.

as the target. The processing of this task could not rely on the well-trained checking or nonchecking decision but it required integrating location and form of the chess piece. If the expert-based priming effects in Experiment 1 are based on more efficient feature-integration processes subliminal priming effects should ensue. If however, these effects are mediated by meaningful chunks of chess configurations (Gobet & Simon, 1996b) no priming should arise, because single piece diagrams do not entail meaningful relations of chess pieces.

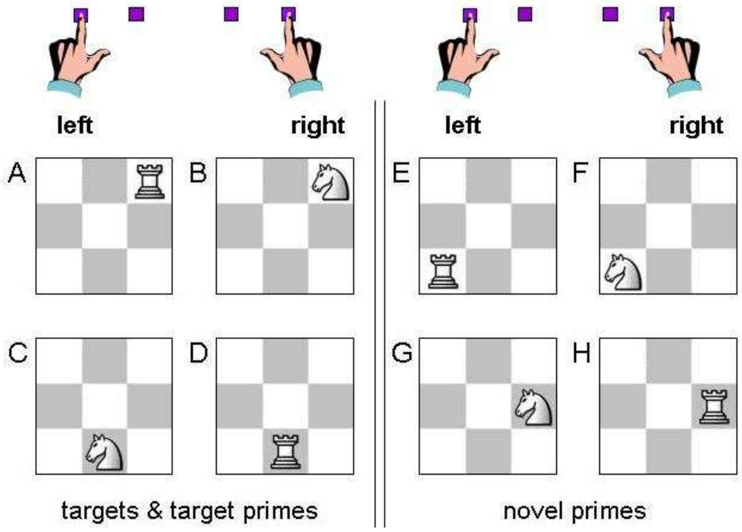

Figure 7. Stimulus set used in Experiment 2: The 3 x 3 grids either afforded one response key (e.g. left), if the rook was presented on a white field or the knight was presented on a black field (Panels A, C, E, and G) and the alternative response key (e.g. right), if the rook was presented on a black field or the knight was presented on a white field diagrammed a checking configuration or a nonchecking configuration (panels B, D, F, and H).The 3x3 grids were either presented as targets as well as primes (panels A, B, C, and D) or only as primes (panels E, F, G, and H).

3.2.1. Method

(1) Participants

12 chess players (aged 18-50; DWZ scores 1384-2227; M = 1750, SD = 292) participated each in an individual session of approximately 55 min. None of them had participated in Experiment 1.

(2) Apparatus, stimuli, design and procedere

Experiment 2 was similar to Experiment 1 except for the following: In the 3x3 grids just a rook or knight was located in one of four positions (upper right, middle right, lower left, and lower middle square). The diagrams with the white piece on the upper right and the lower middle square served as targets as well as target primes (see Figure 7, Panels A, B, C, and D), whereas the diagrams with the white piece on the middle right and the lower left square served as novel primes (Panels E, F, G, and H). Thus, the diagrams used as targets and primes were exactly the same as before in Experiment 1 but without the king. Likewise, the same response was required upon the form and location of the white chess piece. However, instead of performing a check detection task, participants were instructed to respond to press one response key if the rook was presented on a white field or the knight was presented on a black field and the alternative response key if the rook was presented on a black field or the knight was presented on a white field.

3.2.2. Results

(1) Response priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.8 %) were excluded. Mean RTs for correct responses and error rates for each combination of the factors prime congruency and prime type are given in Table 2 (right columns).

An ANOVA on RTs for correct responses with the factors prime congruency and prime type revealed no significant effect, p's > .54. Neither target primes nor novel primes induced a significant congruency effect (separate t-tests revealed p's > .72). The same ANOVA on error rates also revealed no significant effects, p's > .69.

For the experts, responding in this task took much longer on average than in Experiment 1 (see Table 2), validating that in Experiment 2 chess experts performed indeed an XOR-task. To rule out that a possible priming effect faded with longer RTs, the RT distributions in Experiment 2 were again examined. Inspection of Figure 8 clearly rules out this alternative.

Table 2. *Mean RTs for congruent and incongruent primes and the resulting response congruency effects (in ms) for target and novel primes in Experiments 1 and 2.*

	Exp. 1				Exp. 2	
	Experts		Novices		Experts	
	Target Primes	Novel Primes	Target Primes	Novel Primes	Target Primes	Novel Primes
Incongruent Prime	536	534	624	627	681	675
Congruent Prime	521	526	626	627	677	674
Congruency Effect	14**	8*	-1	0	3	1

Note. Asterisks indicate significance level: ** $p < .01$; * $p < .05$ (one-tailed), discrepancies in the computed congruency effect result from rounding errors

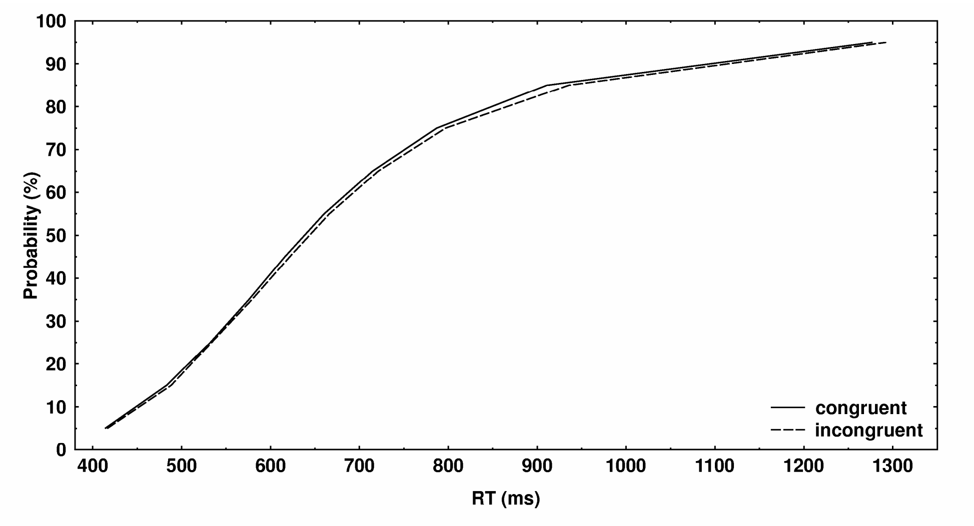

Figure 8. RT distributions depending on Congruency for Experiment 2. Chess experts performing a feature conjunction task did not reveal response congruency effects at any percentile.

(2) Perceptual priming

For the analysis of perceptual priming effects target primes (for location and form effects) and novel primes (for form effects) were analyzed separately.

Target primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.6 %) were excluded. An ANOVA on RTs for correct responses to target primes with the factors location congruency (incongruent and congruent) and form congruency (incongruent and congruent) revealed a significant main effect for form congruency, $F(1, 11) = 5.2$, $p < .05$, $\eta_p^2 = .32$. Participants responded 15 ms faster when the form of the attacker between target and prime diagram was incongruent rather than congruent, indicating a reversed perceptual priming effect for the feature form. Neither the other factor nor the interaction was significant, *ps* > .20.The same ANOVA on error rates revealed no significant effects, *ps* > .50.

Novel primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.4 %) were excluded. For novel primes ANOVAs on RTs as well as on error rates with the factor form congruency revealed no significant effects, *p*s > .11.

(3) Prime visibility

Participants' discrimination performance for check vs. non-check primes was $d' = .047$ and did not deviate significantly from zero, $p > .56$.

3.2.3. Discussion

Chess experts do not reveal subliminal response priming effects in a task that requires integrating location and form of a single chess piece. Thus, it can be ruled out that chess experts are capable of rapidly integrating the features of subliminally presented chess pieces.

Concerning the influence of perceptual priming effects, for target primes there is a reversed perceptual form priming effect. Although the form priming effect did not interact significantly with the factor location congruency, descriptively the form priming effect amounted to -20 ms when the location was incongruent and averaged only to -9 ms when the location was congruent. This difference possibly reflects somewhat an influence of response congruency, because for target primes incongruent form in the case of incongruent location means response congruent, whereas incongruent form in the case of congruent location means response incongruent.

This pattern of results revealing no response priming, no significant effect of location congruency, and a reversed from priming effect, indicates that for chess experts neither the accordance of perceptual features nor response congruence between prime and target diagram did facilitate responses. What cannot be ruled out so far is that in Experiment 2 response priming and perceptual priming largely annihilated each other mutually.

Expert chess players showed subliminal response priming in a task that nominally requires feature integration, but could rely on stored chess configurations

(Experiment 1), whereas they showed no response priming in a task that requires the integration of stimulus features, but could not rely on stored chess configurations (Experiment 2). This suggests that experts' response priming effects (in Experiment 1) are brought about by acquired perceptual chunks that incorporate integrated features of chess pieces' locations and forms. The results of Experiment 1 and 2 extend current knowledge regarding perceptual superiority of experts. Previous studies demonstrated that processing of clearly visible stimuli is automatic because participants were not able to suppress processing of irrelevant distractor check pieces (Reingold, Charness, Schultetus, & Stampe, 2001). Here, it is demonstrated that chess experts process chess configurations even when presented unconsciously.

Taken together, the results of Experiment 1 and 2 also extend our knowledge on unconscious information processing. It was shown that expertise in a certain domain is an important determinant of unconscious processing. Such an observation might be predicted based on previous studies on subliminal priming because these studies used well-known stimulus material (like easy geometrical forms, digits, words, pictures) for which everybody can be considered to be an expert. The present findings suggest that an enormous amount of practice is necessary to enable unconscious stimulus processing because chess novices did not reveal subliminal priming effects for target primes, i.e. for chess configurations that they have seen repeatedly as targets during the experiment.

In addition, chess experts did not reveal subliminal response priming effects in Experiment 2. Obviously at least one condition for expert-specific priming was not met here. These might be the use of stimuli that contained no meaningful relationship between chess pieces, or the use of an untypical task (explicitly combing form and location of chess pieces instead of evaluating the chess configuration). Thus, probably unconscious stimulus processing is restricted to well-trained material and depends on the relevance of the instructed task.

Furthermore, the findings suggest that this impact of expertise on unconscious stimulus processing is unlikely to be mediated by the improvement of task-specific cognitive processes (integration of stimulus features), but instead appears to be based on the substitution of such processes through acquired memories. Expertise thus not only improves task performance but it might also change the nature and phenomenal experience of performing a task by becoming increasingly unconscious.

3.3. Experiment 3: Multiple location-form conjunctions for chess experts

In Experiment 1, chess experts were able to judge unconsciously presented chess configurations as checking or nonchecking (probably due to acquired perceptual chunks), demonstrating complex visual processing outside of conscious awareness. As stimuli in Experiment 1, 3x3 diagrams were used where the black king was always located on the same square while one of two white attackers was located on a square not directly besides the king where it depended on the identity of the attacker whether the king was in check or not. With these constraints, only eight different diagrams were possible and four of them were presented as targets, so that in Experiment 1 participants were able to build up concrete expectations for all possible targets. Nevertheless, this is an astonishing ability, considering that the presented chess diagrams are much more complex than the stimuli that are usually used in priming studies like numbers, letters, words or arrows. However, the question arises to what extend the complexity of the stimuli for the subliminal check detection task can be increased.

Using a combined subliminal priming and task switching paradigm, Kiesel and colleagues (2007a) found priming effects according to currently irrelevant S-R rules. For example, when numbers were used as stimuli and the task in a trial was either number classification or parity judgement, priming effects for both tasks (also the irrelevant one) were observed. In line with models of prime activation, it was suggested “that at least two routes may gain access on response processes simultaneously” (Kiesel et al., 2007a, p. 89). In Kiesel and colleagues’ experiment (2007a), a number contained both, information about its value und parity. Likewise in Experiment 1, to resolve the check detection task, both features (location of form) of the attacker had to be considered. For chess experts however, the impact on response priming in Experiment 1 did not necessarily derive from a parallel activation of two features rather than from an integration of both features. Nevertheless, in a check detection task with visible diagrams, it was found that chess experts are able to process relations of different chess pieces automatically and in parallel (Reingold, Charness, Schultetus, & Stampe, 2001).

Thus, in order to elaborate whether chess experts are able to process the information given in unconsciously presented chess diagrams in parallel, in

Experiment 3 additionally the location of the king was varied (see Figure 9). As a consequence, both the form (or colour because the king was always black and the attacker was always white) and the location of two pieces have to be combined in order to differentiate checking diagrams from nonchecking diagrams. If chess experts were able to classify these diagrams without conscious identification of the diagrams, this would demonstrate an even major ability of expert chess players in processing complex stimuli unconsciously.

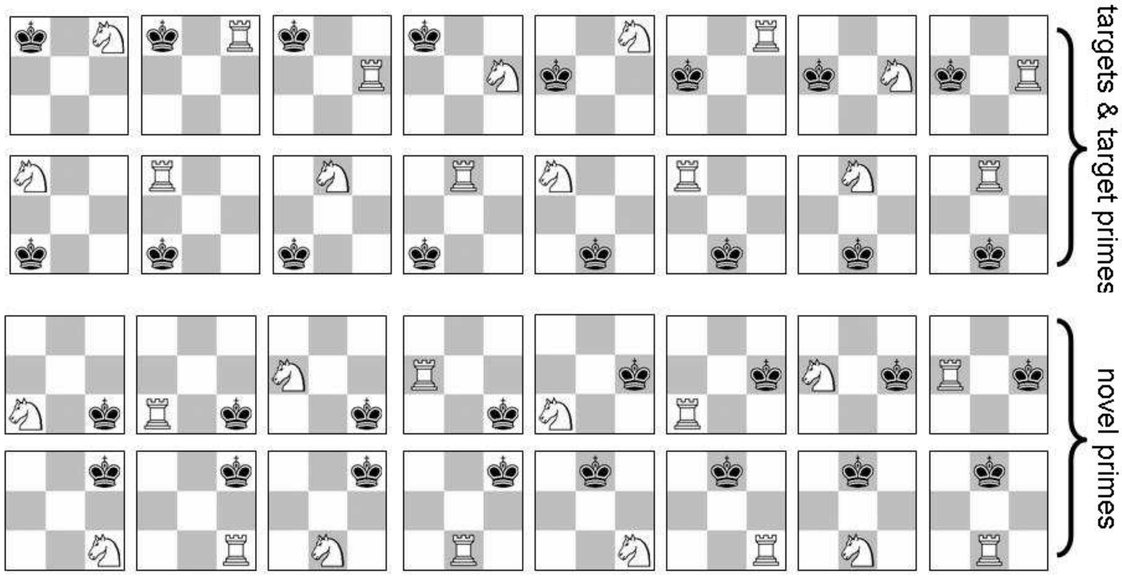

Figure 9. Stimulus set used in Experiment 3: The 3 x 3 grids either diagrammed a checking configuration or a nonchecking configuration. They were either presented as targets (first and second row) as well as target primes (first and second row) or novel primes (third and forth row). There were eight possible locations for the black king – upper left, upper middle, middle left, or lower left square (in targets and target primes) and lower middle, lower right, middle right, or upper right square (in novel primes).

3.3.1. Method

(1) Participants

12 chess players (aged 16-50, mean 36.5; DWZ scores 1291-2310, mean 1749.9) that had not taken part in one of the former experiments participated each in an individual session of approximately 55 min in exchange for pay. All reported having normal or corrected-to-normal vision, and were not familiar with the purpose of the experiment.

(2) Apparatus and stimuli

Experiment 3 was similar to Experiment 1 except for the following: In the 3x3 grids not only the position of the white attacker (rook or knight) but also the position of the king varied. In 16 different target diagrams (see Figure 9, first and second row) the black king was located either on the upper left, on the upper middle, on the middle left, or on the lower left square. A white rook or knight was located in one of four opposing positions (upper left, upper middle, upper right, and middle left square). Thus, for each of the four possible locations for the king there were two opposite squares were either rook or knight were presented. At each square one attacker was giving check to the king whereas the other attacker was giving no check to the king. All 16 target diagrams were also presented as primes[7].

[7] Due to a programming error, for half of the participants the diagrams with the king on the lower middle and the knight on the upper middle square as well as with the king on the lower left and the knight on the upper middle square were not presented as target primes, instead the diagrams with the king on the lower middle and the knight on the upper left as well as the king on the lower left

Additionally there were 16 novel prime diagrams (see Figure 9, third and forth row) in which the black king was located either on the lower middle, on the lower right, on the middle right or on the upper right square. A white rook or knight was located in one of four opposing positions (middle right, lower left, lower middle and lower right square). Again, at each square one attacker was giving check to the king whereas the other attacker was giving no check to the king.

(3) Design and procedere

In Experiment 3, participants were instructed to indicate whether the target diagrammed a checking or a nonchecking configuration by pressing a left or right key. In other aspects, Experiment 3 was also similar to Experiment 1 except the following: The extended stimuli set consisted of 10 blocks with 640 trials altogether. In the first eight blocks each combination of prime (32) x target (16) was presented once. In block nine and ten 128 additional trials were selected without replacement from the 512 possible prime x target-combinations.

Participants were fully informed about the structure of the prime stimuli and were then presented with 128 trials for which they were to discriminate whether the prime diagrammed a checking or a nonchecking configuration. These trials were also selected by chance without replacement, but now exactly half of them diagrammed a checking configuration as prime, whereas the other half diagrammed a nonchecking configuration as prime.

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and the knight on the upper left square were presented to them as target primes. However, the proportion of response congruent and response incongruent trial was not affected by this error.

3.3.2. Results

(1) Response priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.2 %) were excluded. Mean RTs for each combination of the factors prime congruency and prime type are given in Table 3.

An ANOVA on RTs with the factors congruency and prime type revealed no significant effect, p's > .13. Neither target primes nor novel primes induced a significant congruency effect (separate t-tests revealed p's > .25).

The same ANOVA on error rates revealed a significant interaction of the factors congruency and prime type, $F(1, 13) = 7.8$, $p < .05$, $\eta_p^2 = .38$. Neither the main effect of the factor congruency nor the main effect of the factor prime type approached significance, *ps* > .17. Single comparisons revealed a congruency effect for target primes $t(13) = 2.3$, $p < .05$, whereas novel primes induced a marginally significant reversed congruency effect $t(13) = -1.9$, $p = .075$.

Table 3

Mean RTs (in Milliseconds) and Percentages of Errors for response priming and perceptual priming in Experiment 3, including target and novel primes, incongruent and congruent primes, and the resulting congruency effects (in ms)

	Response priming		Perceptual priming		
	Target primes	Novel primes	Target primes		Novel primes
			Location	Form	Form
RTs					
Incongruent prime	569 (20.4)	571 (19.2)	574 (19.8)	573 (20.0)	568 (19.1)
Congruent prime	574 (20.8)	569 (19.2)	566 (22.0)	568 (21.7)	572 (18.5)
Congruency effect	-5	3	8	5	-4*
Error rates					
Incongruent prime	6.4 (1.0)	5.8 (1.1)	5.2 (0.9)	6.3 (1.1)	5.7 (1.0)
Congruent prime	5.1 (0.9)	6.9 (0.9)	6.8 (1.1)	5.7 (0.9)	7.0 (1.0)
Congruency effect	1.3*	-1.0	-1.4	0.6	-1.3

Note. Corresponding standard errors are shown in parantheses. Discrepancies in the computed congruency effect result from rounding errors. RTs = reaction times. * $p < .05$

(2) Perceptual priming

For the analysis of perceptual priming effects target primes (for location and form effects) and novel primes (for form effects) were analyzed separately. RTs for correct responses and error rates for each combination of the factors location congruency and form congruency for target primes and for the factor form congruency for novel primes are given in Table 3.

Target primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.3 %) were excluded. An ANOVA on RTs for correct responses to target primes with the factors location congruency (incongruent and congruent when at least the attacker or the king was located on the same square) and form congruency (incongruent and congruent) revealed no significant effects, *ps* > .13.The same ANOVA on error rates revealed a marginally significant main effect of the factor location congruency, $F(1, 13) = 3.8$, $p = .075$, $\eta_p^2 = .22$, whereas neither the main effect for factor form nor the interaction of both factors reached significance, ps > .50.

Novel primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.1 %) were excluded. For novel primes an ANOVA on RTs with the factor form congruency revealed a reversed form priming effect, $F(1, 13) = 5.6$, $p < .05$, $\eta_p^2 = .30$. The same ANOVA on error rates revealed a marginally significant form priming effect, $F(1, 13) = 3.9$, $p = .069$, $\eta_p^2 = .23$.

(3) Prime visibility

Participants' discrimination performance for check vs. non-check primes was $d' = -.0006$ and did not deviate significantly from zero, $p > .98$.

3.3.3. Discussion

In Experiment 3, where 16 different 3x3 chessboards were presented as targets with varying locations for king and attacker, response priming for chess experts for target as well as for novel primes was largely eradicated. At first sight, this result is in contrast to a typical observation made in subliminal priming experiments, because increasing the size of the target set, usually increases the impact of target primes (at least in lexical decision and naming experiments; van den Bussche et al., 2009) as well as novel primes (Kiesel, et al., 2006; Pohl et al., 2010).

However, Abrams (2008a) pointed out that besides target set size, the category size, where the targets are taken from, also influences the effectiveness of novel primes. Within a small target set, novel primes elicited priming effects when the category size was small but not when it was large. Support for the notion that increasing category size diminishes priming, comes from a meta-analysis of semantic priming experiments. Van den Bussche and colleagues (2009) found that the size of the category strongly moderated the effect sizes of priming effects. The average effect size for stimuli from large categories just amounted 0.38 and was almost three times smaller than the average effect size for stimuli from small categories which amounted 1.09. With the constraints in Experiment 3 – the number of potential targets is indeed limited, however in Experiment 3 not only the target set size but also the category size[8] was substantially larger than in Experiment 1. A plausible explanation for the absence of response priming effects in Experiment 3 and for the observation of diminished priming when large categories are used, is that is more difficult to form specific expectations when the experienced targets come from large categories. It has already been shown that subliminal primes only elicit response priming effects when they are currently expected (e.g. Kunde et al., 2003; 2005) and that these expectations can be very precise (Elsner et al., 2008; Kunde et al., 2003, Exp. 3; Pohl, et al., 2010). When the category size is as small as in Experiment 1, it is likely that participants are able to form specific expectations for all potential targets, as long as they are familiar enough (i.e. chess experts in Experiment 1) with the presented stimuli. However, when the category gets wider like in Experiment 3, even for experts it becomes impossible to form distinct anticipations (i.e. action triggers) for all possible targets and to differentiate them offline in appropriate release conditions for a left or right response. As a consequence, for experts the situation in Experiment 3 was more difficult and similar to the situation of novices in

[8] Category size normally (e.g. Abrams, 2008a) refers either to small categories such as farm animals or fruits or large categories such as things smaller or larger than the monitor. With regard to this distinction, the stimuli used in Experiment 1 and 3 (3x3 chessboards with a black king and a white attacker) both belong to a small category. However, in Experiment 1, the constraints in the presented targets (a black king always located on the upper left corner and a white attacker which was either a knight or a rook and which was never located on a square adjacent to the king) imply that only few different targets are possible, whereas in Experiment 3, the constraints were broader (multiple locations of the king) so that much more different targets were possible. Therefore, it makes sense to distinguish between a smaller category in Experiment 1 and a larger category in Experiment 3.

Experiment 1, who were unable to from action triggers. Support for this assumption comes from the contrast of overall response times between Experiment 1 and 3. Responding in the check detection task in Experiment 3 took experts substantially longer than in Experiment 1 (571 ms in Experiment 3 vs. 529 ms in Experiment 1).

In the error rates, there was a response priming effect for target primes and a marginally significant reversed response priming effect for novel primes. However, it seems advisable to be cautious in interpreting this result as evidence for unconscious prime processing, because usually the RT measure is more sensitive for subliminal priming effects than the error rates and for target primes there was no response priming at all in reaction times. Moreover, the response priming effect in error rates for novel primes goes in the opposite direction. So, it is yet unclear how this pattern of results developed.

In Experiment 3, there is also evidence for perceptual influences. Target primes elicited a marginally significant location priming effect in error rates and novel primes elicited a marginally reversed form priming effect in reaction times as well as a reversed form priming effect in error rates. Location priming for target primes is in line with subliminal exogenous cuing (e.g. McCormick, 1997; Mulckhuyse et al., 2007). However, it is rather difficult to explain the reversed form priming effect for novel primes, indicating that participants responded faster and less error prone when in novel prime diagram and target diagram the form of the attacker was different, whereas for target primes the pattern of form priming results is – at least descriptively – reversed. In Experiment 3, with so many different diagrams and prime-target combinations, there are lots of possible low level perceptual influences that cannot be controlled entirely. On the one hand, with varying locations of the king, when presented on possible locations for the attacker, the form of the king may also play a role for form priming in a way that the form of the king in the prime diagram could interact with the form of the attacker in the target diagram. Similarly, it is possible that the form of the attacker (or of one of the attackers – either the knight or the rook) facilitates perception of the king and therefore contaminates form priming effects that are calculated solely for the form congruence of the attacker. On the other hand, there a several different location congruencies that have to be considered. In the analysis of experiment 3, the factor location congruency was defined as either "incongruent or congruent when at least the attacker or the king was located on the same square" (p. 88 in this work). However, it is also possible to differentiate more precisely between congruence of the king and congruence of the attacker. I ran an additional ANOVA to account for this posibility: An ANOVA on RTs for correct responses to target primes with the factors location congruency (incongruent, attacker congruent, king congruent, and both congruent) and form congruency (incongruent and congruent) revealed no significant effects, *ps* > .18. The same ANOVA on error rates revealed a significant interaction between location and form, $F(3, 39) = 3.3$, $p < .05$, $\eta_p^2 = .20$, whereas both single factors were not significant, *ps* > 40. Planned comparisons revealed a significant form priming effect when the location of both pieces in the diagram was the same in prime and target diagram, $t(13) = 2.2$, $p < .05$, indicating that in this case participants made more errors when the attacker's form in prime and target diagram was different (8.4 %) vs. same (2.6 %). For the other cases of location congruency there were no significant differences between congruent and incongruent form, *ps* > .32. Now, location priming is absent and the form priming effect that emerges when the attacker in prime and target diagram are located on the same square, possibly reflects somehow an influence of response congruence. However, there was no response priming effect for target primes, not even descriptively. So, the results of this additional analysis cannot be interpreted properly. Moreover, there are further influences of location congruency (e.g. congruence of the location of the attacker and the king) that are not yet examined. But every further analysis would give rise to alpha inflation and even still significant results would only be post hoc explanations.

To sum up, I still cannot sufficiently explain the reversed form priming effect and also the other results in error rates (marginal location priming effect as well as response priming effect for target primes and a marginally significant reversed response priming effect for novel primes) should be taken cautiously. In Experiment 3, there were too many potentially influencing perceptual factors that cannot be controlled and that possibly contaminated the response priming and even the perceptual priming results. Therefore, in the following experiments I will concentrate on perceptual (location and form) influences in a response priming paradigm under better controlled conditions.

4. Unconscious processing of single features

Although in the last decades, many studies have explored the nature and the mechanisms of subliminal priming, almost all of them have been focusing either on response priming, or on perceptual priming. Within each paradigm the impact of different influences on priming has been opposed. For example, investigating the formation of response priming, some studies (Abrams, 2008b; Abrams & Greenwald, 2000; Greenwald et al., 2003) as well as a meta analysis (Van den Bussche et al., 2009) found that S-R priming is stronger than semantic priming. However, to the best of my knowledge, perceptual priming and response priming had not been contrasted directly yet. Therefore, the question that motivated the following experiments was, what happens when the meaning of a stimulus (as a whole) is different from the perceptual facilitations (from its parts) it brings about to the target? That is, which response is easier when the instructed as well as learned response (response priming) is the opposite of the perceptual facilitated response (perceptual priming)?

The design and the stimuli already used in Experiment 1 are suitable to answer these questions. In order to investigate the impact of expertise in processing complex visual stimuli outside of awareness, I compared chess experts and novices with a subliminal check detection task. Stimuli used as primes as well as targets were partial chessboards measuring 3x3 squares with a black king and a white attacker (a rook or knight located on one of two different squares). Participants judged whether a target chess configuration entailed a checking or a nonchecking configuration. In contrast to novices, chess experts revealed a subliminal response priming effect. That is, they responded faster when prime and target diagrams were congruent (both checking or both nonchecking) rather than incongruent, irrespectively of the location (which square) and form (rook or knight) of the attacker. The result was interpreted by experts capability to activate or rely on acquired perceptual chunks in which the critical features (location and form) of the attacker and its relation to the king were already integrated. Novices on the other hand elicited no response priming effect. However, additional analyses revealed indications for perceptual facilitation when the location or the form of the attacker was the same in prime and target diagram even when prime and target diagram were response incongruent. The current experiments investigate these effects of location and form priming opposed to response priming in more detail.

4.1. Experiment 4: Contrasting response priming and perceptual priming

Experiment 4 was conducted to contrast priming by the low level perceptual features location and form with response priming. Stimuli were 3x3 chessboards that either diagrammed a checking or a nonchecking configuration. A black king was always presented in the upper left corner. A white attacker was presented on one of two different locations (upper right corner and lower middle square) and in one of two different forms (either rook or knight). Participants pressed one response key for a checking position and another response key for a nonchecking configuration (for similar check detection tasks see Bilalić et al., 2011; Reingold, Charness, Pomplum, & Stampe, 2001; Saariluoma, 1985). A rook diagrammed in the upper right corner represents a checking configuration (see Figure 10, panel A), whereas a knight diagrammed in the upper right corner represents a nonchecking configuration (panel B). In contrast, a rook diagrammed in the lower middle square represents a nonchecking configuration (panel D), whereas a knight diagrammed in the lower middle square (panel C) represents a checking configuration.

So, to decide whether the king is in check or not, it was necessary to integrate both features of the attacker. Neither its location nor its form alone is informative for the required response, because 50 % of all diagrams containing for example a knight represent a checking situation (when the knight is diagrammed in the lower middle square) and also 50 % of all diagrams in which the attacker is located for example at the lower middle square represent a non-checking situation (when the rook is diagrammed in the lower middle square). Thus, the applied check detection task constitutes an XOR problem because two diagrams require the same response (i.e. are congruent) either when both features, form and location in relation to the king, are the same or both differ, whereas two diagrams require different responses (i.e. are incongruent) if one feature is repeated while the other changes.

Before each target configuration, a prime configuration was shown briefly and masked immediately so that participants were unable to consciously perceive the prime configuration. With the same four diagrams as target and prime (so-called target primes), this design allows to disentangle within a trial response priming and perceptual priming and to differentiate between three congruency cases: response congruency, location congruency and form congruency. First, responses for prime and target diagram are congruent when both prime and target diagram show a checking or a nonchecking situation (see Figure 10, panels A-A, A-C, B-B, B-D, C-C, C-A, D-D, D-B), otherwise they are incongruent (A-B, A-D, B-A, B-D, C-B, C-D, D-A, D-C). Second, the location of the attacker in prime and target diagram is congruent when the pieces are diagrammed on the same square (A-A, A-B, B-B, B-A, C-C, C-D, D-D, D-C) and incongruent when the pieces are diagrammed on two different squares (A-D, A-D, B-C, B-D, C-A, C-B, D-A, D-B). Finally, the form of the attacker in prime and target diagram is congruent when the same piece is diagrammed in both diagrams (A-A, A-D, B-B, B-C, C-C, C-B, D-D, D-A) and incongruent when two different pieces are presented (A-B, A-C, B-A, B-D, C-A, C-D, D-B, D-C). Thus, when identical prime-target repetitions are excluded then response congruency is associated with location incongruency as well as form incongruency. On the other hand, location congruency and form congruency are associated with response incongruency.

In addition, four additional diagrams were only presented as primes. In these diagrams rook and knight were diagrammed on two other squares (middle right and lower left). These prime configurations (novel primes) were never used as target stimuli, that is, participants never categorized them consciously. They were included to examine whether response priming or perceptual form priming may even transfer to unseen chess diagrams. Measurement of perceptual location priming was not possible with these novel primes because here the location of the attacker always differs between prime and target diagram, i.e. is incongruent. Again, responses for prime and target diagram are congruent when both prime and target diagram diagram are checking or nonchecking situation (see Figure 10, panels E-A, E-C, F-B, F-D, G-C, G-A, G-C, H-B, H-D), otherwise they are incongruent (E-B, E-D, F-A, F-C, G-B, G-D, H-A, H-C). On the other hand, the form of the attacker in prime and target diagram is congruent when in both diagrams the same piece is diagrammed (E-A, E-D, F-B, F-C, G-B, G-C, H-A, H-D) and incongruent when two different pieces are presented (E-B, E-C, F-A, F-D, G-A, G-D, H-B, H-C).

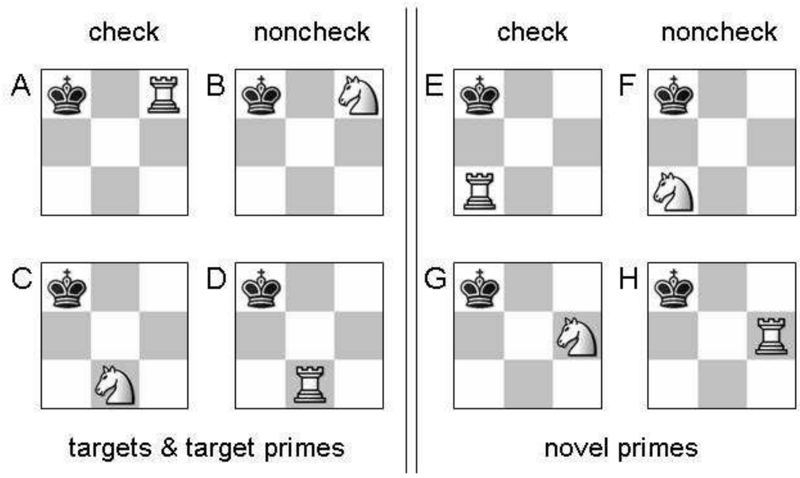

Figure 10. Stimulus set used in Experiment 4: The 3 x 3 grids either diagrammed a checking configuration (panels A, C, E, and G) or a nonchecking configuration (panels B, D, F, and H). They were either presented as targets as well as target primes (panels A, B, C, and D) or only as novel primes (panels E, F, G, and H).

Unconscious processing of the configuration as a whole picture would be indicated by a response priming effect, i.e. faster responses when both prime and target configurations were checking or both were nonchecking (response congruent trials) than when one configuration was checking but the other was not (response incongruent trials). In contrast, unconscious processing of the single features location or form would be indicated by a perceptual priming effect, i.e. faster responses when the location or the form of the attacker in both prime and target configurations is congruent rather than incongruent. Yet, in order to boost prime induced activation prime duration was increased from 20 ms (in Experiment 1) to 29 ms.

4.1.1. Method

(1) Participants

20 participants (aged 19-29, mean 20.6; all were chess novices and reported having played no more than 100 games in their life) took part in an individual session of approximately 55 min. All participants declared having normal or corrected-to-normal vision and were not familiar with the purpose of the experiment.

(2) Apparatus and stimuli

An IBM-compatible computer with a 17 inch (43 cm) VGA-Diagram (vertical retraces 70 Hz) and an external keyboard were used for stimulus presentation and response sampling. Stimuli were eight pictures of minimized 3x3 chessboards extending 45 x 45 mm. The king was always located in the upper left corner. The attacker, either rook or knight, was located in one of four positions (upper right, middle right, lower left, and lower middle square). Four of the chessboards (rook or knight located in the upper right or lower middle square) served as targets. All eight chessboards were used as primes, enabling us to compare the effects of novel and target primes. Masks were random dot patterns extending 80 x 80 mm. Additionally, the prime picture as well as the target picture were also presented with a random dot pattern frame.

(3) Design and Procedure

Each trial started with an empty 3 x 3 grid with a fixation cross in the middle presented for 200 ms. Premask, prime, postmask, and target were then presented. To enhance masking, premask and postmask consisted of five different random dot patterns with a total duration of 72 ms (5 x 14.3 ms). Prime duration was 29 ms (2 refresh cycles); target duration was 250 ms.

Participants were instructed to indicate whether the target diagrammed a checking or a nonchecking configuration by pressing a left or right key. Errors and missing responses (exceeding 5 sec after target onset) were fed back.

The experiment consisted of 10 blocks in which each combination of prime (8) x target (4) was presented twice in random order (640 trials altogether). It finished with a detection task to test participants' awareness of the primes. Participants were fully informed about the structure of the prime stimuli and were then presented with 128 identical trials for which they were to discriminate whether the prime diagrammed a checking or a nonchecking configuration. For the detection task, participants were instructed to take their time and to try to be as accurate aspossible. In order to avoid that unconsciousness congruency effects influence the free response choice (see Kiesel, Wagener, et al., 2006; Schlaghecken & Eimer, 2004), there was an interval of 800 ms after target offset, in which no response was possible (adopted after Vorberg et al., 2003).

4.1.2. Results

The factors response congruency, location congruency and form congruency can not be considered within one single analysis. They are not orthogonally varied. I therefore report in the following first response priming and then perceptual priming (location priming and form priming).

(1) Response priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.1 %) were excluded. Mean RTs for correct responses and error rates for each combination of the factors prime type and response congruency are given in Table 4.

An ANOVA on RTs for correct responses with the factors prime type (target primes and novel primes) and response congruency (congruent and incongruent) revealed a marginally significant main effect for prime type, $F(1, 19) = 1.6$, $p < .10$, $\eta_p^2 = .14$, and a significant main effect for response congruency, $F(1, 19) = 5.9$, $p < .05$, $\eta_p^2 = .24$. The interaction between prime type and response congruency was not significant, $p = .23$. The same ANOVA on error rates revealed no significant effects *p*s > .46.

Table 4

Mean RTs (in Milliseconds) and Percentages of Errors for response priming and perceptual priming, for target and novel primes, for incongruent and congruent primes and the resulting congruency effects (in ms) in Experiment 4

	Response priming			Perceptual priming		
	Target primes		Novel primes	Target primes		Novel primes
Variables	Inclusive identical repetitions	Without identical repetitions	Without identical repetitions	Location	Form	Form
RTs						
Incongruent prime	610 (18.7)		603 (19.2)	620 (18.4)	616 (18.7)	604 (18.9)
Congruent prime	602 (19.7)	626 (18.7)	601 (19.1)	591 (19.8)	594 (19.4)	600 (19.8)
Congruency effect	9	-16*	1	29***	22***	4
Error rates						
Incongruent prime	6.5 (1.0)		6.9 (0.9)	7.5 (1.0)	6.7 (1.0)	6.5 (1.0)
Congruent prime	7.1 (0.8)	7.7 (1.0)	6.7 (1.0)	6.1 (0.9)	7.0 (0.9)	7.1 (1.0)
Congruency effect	-0.6	-1.1	0.1	1.4*	0.3	0.6

Note. Corresponding standard errors are shown in parantheses. Discrepancies in the computed congruency effect result from rounding errors. RTs = reaction times.

* $p < .05$, ** $p < .01$, *** $p < .001$.

On average, participants responded faster for congruent than for incongruent trials. However, as can be seen in Table 4, this effect only derives from target primes and not from novel primes (9 ms versus 1 ms response priming effect). Moreover, removing identical prime-target repetitions, that is diagrams in which both the location and the form of the attacker are the same in prime and target diagram (A-A, B-B, C-C, D-D, see Figure 10), reverses the response congruency effect. A subsequent ANOVA for RTs with the same factors revealed a significant main effect for response congruency, $F(1, 19) = 8.7$, $p < .01$, $\eta_p^2 = .32$, a significant main effect for prime type, $F(1, 19) = 33.1$, $p < .001$, $\eta_p^2 = .64$ and a significant interaction between prime type and response congruency, $F(1, 19) = 6.3$, $p < .05$, $\eta_p^2 = .25$. Single comparisons revealed that there is now a reversed response congruency effect for target primes $t(19) = -2.9$, $p < .01$, but no congruency effect for novel primes, $p > .56$.

(2) Perceptual priming

For the analysis of perceptual priming effects target primes (for location and form effects) and novel primes (for form effects) were separately analyzed. Mean RTs for correct responses and error rates for each combination of the factors location congruency and form congruency for target primes and for the factor form congruency for novel primes are given in Table 4.

Target primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.4 %) were excluded. Averaged data across all participants are presented in Figure 11.

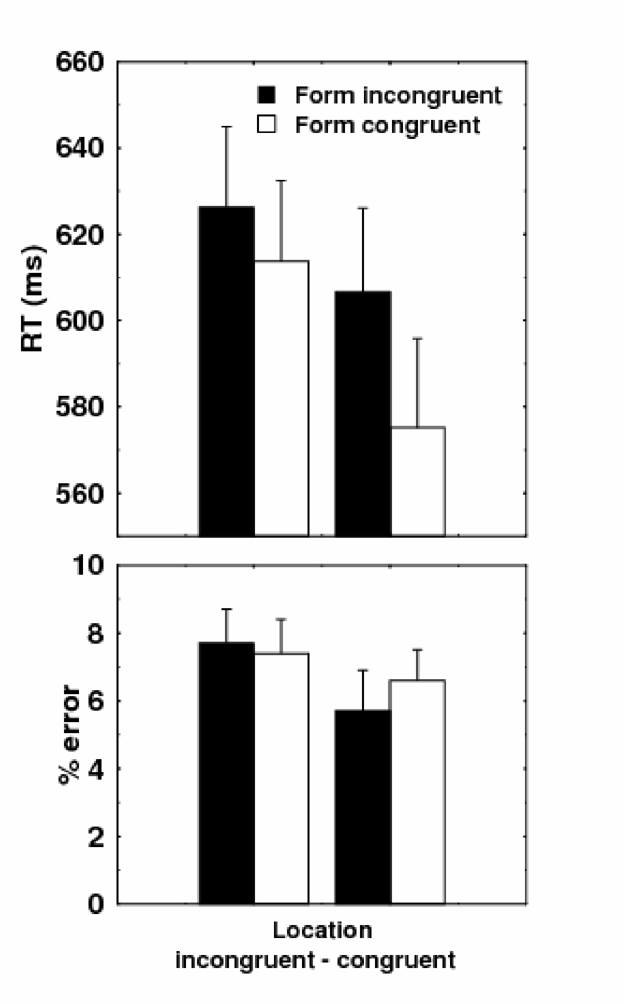

Figure 11. Novices mean RTs (upper panel) and error rates (lower panel) for target primes depending on perceptual congruency (location and form) in Experiment 4. Lines represent standard errors.

An ANOVA on RTs for correct responses to target primes with the factors location congruency (incongruent and congruent) and form congruency (incongruent and congruent) revealed significant main effects for location congruency, $F(1, 19) = 33.0$, $p < .001$, $\eta_p^2 = .64$, and form congruency, $F(1, 19) = 30.1$, $p < .001$, $\eta_p^2 = .61$, as well as a marginally significant interaction between location congruency and form congruency, $F(1, 19) = 4.3$, $p < .06$, $\eta_p^2 = .18$. As this interaction is ordinal, it is allowed to interpret both main effects. Participants responded faster when either the location or the form of the attacker was the same in prime and target diagram (620 ms different location vs. 591 ms same location; 616 different form vs. 594 same form). The interaction derives from especially fast responses when both form and location are congruent, that is for identical prime-target diagrams.

The same ANOVA on error rates (see Figure 11) revealed a significant main effect for location congruency $F(1, 19) = 4.7$, $p < .05$, $\eta_p^2 = .20$, indicating that participants made more errors when the attacker's location in prime and target diagram was different (7.5 %) vs. same (6.1 %). The other factor and the interaction revealed no significant effects, *ps* > .34.

Novel primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.1 %) were excluded. For novel primes ANOVAs on RTs as well as on error rates with the factor form congruency revealed no significant effects, *p*s > .34.

(3) Prime visibility

Participants' discrimination performance for check vs. non-check primes was $d' = .252$ and deviated significantly from zero, $t(19) = 3.5$, $p < .01$.

To test whether the priming effects for target primes are related to individual prime visibility, a regression analysis as proposed by Draine and Greenwald (1998, see also Greenwald, et al. 1995; Greenwald, et al. 1996) was computed. For response priming as well as perceptual priming (location and form priming), a priming index was calculated for each participant, with index = 100 x (RT incongruent – RT congruent) / RT congruent. Individual priming indices were regressed onto the individual *d´* values. The linear regression analysis revealed a significant correlation between *d'* and the priming index for response priming r = .606, F(1, 19) = 10.43, p < .001, indicating that better visibility (individual *d´*-values reached from to -.16 to 1.05) causes higher response priming effects. The intercept of the regression was also larger than zero (intercept = .15, t(19) = 2.23, p < .05), indicating that significant responsel priming effects are associated with *d'*-values of zero.

The same linear regression analysis revealed no significant correlation between *d'* and the priming index neither for location priming r = .234, F(1, 19) = 1.05, p > .32, nor for form priming r = .168, F(1, 19) = .52, p > .48. The intercept of the regression was larger than zero for location priming (intercept = 4.47, t(19) = 3.41, p < .01) as well as for form priming (intercept = 4.36, t(19) = 3.34, p < .001), indicating that significant perceptual priming effects are associated with *d'*-values of zero.

4.1.3. Discussion

In Experiment 4, stimuli that consisted of two different features (location and form of an attacking piece on a chessboard), a (XOR-)task that makes feature integration necessary (check detection), and a prime duration of 29 ms were used.

The results are clear-cut. For target primes, I found possible evidence for response priming as well as strong perceptual priming effects. For novel primes, however, neither response priming nor perceptual form priming was present.

In Experiment 4, strong perceptual location priming and strong perceptual form priming is evident as well as an almost significant interaction of these two factors. The marginally significant interaction between the two factors location congruency and form congruency indicates that the impact of the two perceptual effects is either over additive or that response priming plays also a role for response facilitation.

A closer inspection of the four bars in Figure 11 (upper panel) that depict the RT data for target primes illustrates the results. Response time depended on whether the perceptual features location and form of the attacker in prime and target diagram were congruent or not, resulting in four different cases. First, when location as well form were incongruent (what is a response congruent case), participants needed on average 626 ms (left black bar) to respond. Second, when location was incongruent but form was congruent (what is a response incongruent case), participants needed on average 614 ms (left white bar) to respond. Third, when location was congruent but form was incongruent (what is a response incongruent case), participants needed on average 606 ms (right black bar) to respond. And finally, when location as well as form were congruent (what is a response congruent case), participants needed on average 575 ms (right white bar) to respond.

So, it becomes clear that the impact of every single perceptual feature (location or form) is even stronger than the response priming effect. Nevertheless, it seems to be that response congruency had an - although inferior – additional influence. However, it is also possible that there is no response priming at all. The indication for response priming comes mainly from the observed response facilitation in the trials were all influencing factors (response, location and form) were congruent. We do not know whether in these trials the impact of the perceptual features is over additive, i.e. that very strong perceptual facilitation takes place when both perceptual features are congruent. Then the observed response priming effect would be just an artifact of the (almost significant) interaction of location and form priming.

Compared with Experiment 1, increasing the prime duration for target primes from 20 ms to 29 ms was sufficient to elicit possibly response priming as well as strong perceptual priming. As already reported in Experiment 1, with a prime duration of 20 ms there was no indication for response congruency effects for novices. For similar results see Kunde and colleagues (2005) and Jaskowski and Przekoracka-Krawczyk (2005) who already showed that a higher visibility of the primes is associated with lager priming effects.

In Experiment 4, prime diagrams where the attacker is located on novel – and therefore unexpected – squares did not elicit - response priming or form priming effects. This top down influence even on perceptual – low level – priming effects is in line with studies demonstrating that masked priming is influenced by top down processes like spatial attention (Ansorge & Heumann, 2006; Besner et al., 2005; Lachter et al., 2004; Sumner, Tsai, Yu, & Nachev, 2006) and stimulus expectations (Kunde, et al., 2003; Pohl et al., 2010; Van den Bussche, Segers, & Reynvoet, 2008).

Perceptual form priming depends on expected stimulus locations. This result may help to solve an open question regarding attentional modulation of repetition priming effects. On the one hand, there are two accounts stating that only semantic categorical priming effects are modulated by attention, whereas low-level repetition priming is considered as an automatic process (Fabre, Lemaire, & Grainger, 2007; Sumner, et al., 2006). On the other hand, several studies demonstrate that repetition priming is indeed modulated by attention (Besner et al., 2005; Lachter et al., 2004; Marzouki, Grainger, & Theeuwes, 2007; Van den Bussche, Hughes, Van Humbeeck, & Reynvoet, 2010). The present results favour the later conclusion because perceptual form priming in Experiment 4 was modulated by spatial attention i.e. expectations of possible stimulus locations, because only target primes elicited perceptual form priming. The present finding extends these studies in two ways.

First, contrary to Besner and colleagues (2005), Van den Bussche and colleagues, (2010), and Lachter and colleagues (2004, Exp. 5), in Experiment 4, there was neither a trial by trial cuing of the target location nor was the target always presented on a fixed location as in Lachter and colleagues' study (2004, Exp. 1 and 2). Instead, in Experiment 4, the attacker was presented on one of two different squares with equal probability and perceptual form priming was absent when the attacker in the prime diagram was presented on one of two squares adjacent of the two possible locations of the attacker in the target diagram. Therefore, it seems to be that participants built up expectations solely of the two squares where the attacker was located in the target diagram.

What we do not exactly know is whether both possible locations of the attacker were expected simultaneously or whether alternating attention was directed only to one of these two locations. The huge bunch of observations made with supraliminally presented stimuli summarized in the spotlight metaphor of attention (e.g. Müller & Krummenacher, 2002) suggests that visual attention can not be separated. Although it is possible to direct attention independently from fixation, it is stated the spot cannot be directed to different locations at the same time. Visual attention is rather continuously allocated in space (e.g. Eriksen & Yeh, 1985; Posner et al., 1980; however see Awh & Pashler, 2000, who demonstrated that it is also possible to split the focus of attention in at least two foci). Within the same line is the result of a subliminal priming experiment where always two primes were presented at the same time. Elsner, Kunde, and Kiesel (2007) presented a number target either above or below fixation, and two primes were presented concomitantly on both locations. Analyzing RT distributions they showed that only one of two primes at a time contributed to the priming effect. Thus, it is more likely that the observed form priming effect in our experiment originates from (approximately 50% of the) trials in which attention was directed in advance the location of the attacker in the prime diagram.

Second, in semantic categorical as well as in repetition priming low-level perceptual effects and response priming effects go in the same direction i.e.

facilitating the same response. In contrast, in Experiment 4 perceptual form priming is independent of response priming, because form priming is evident even when responses to prime diagram and target diagram are different. However, this is only the case for prime diagrams where the attacker is located on one of the two possible squares were the attacker is presented in the target diagram. When the attacker in the prime diagram is located on another (not top down expected square), then no perceptual form priming is observed.

4.2. Experiment 5: Training study

In contrast to chess experts, novices elicited no priming in Experiment 1, whereas Experiment 4 revealed strong perceptual location and form priming effects as well as evidence for response priming but only for (identical) target primes.

It is conceivable that novices' lacking training experience with chess material and the piece relations hinders response priming. The classical work by Shiffrin and Schneider (1977; see also Schneider & Schiffrin, 1977) suggests that integrations of visual stimuli can be acquired by extensive practise. In one of Shiffrin and Schneiders experiments, participants responded few thousand times again and again to the same few letters (deciding whether some letters are presented among other letters). As a result of training the target letters attracted attention automatically, indicating that an acquired unitary neural representation i.e. an integrative representation of the experienced letters led to an automatic response initiation for the whole learned letter set. Not formal similarities between the letters but the same responses to perceptually different stimuli were decisive for building up a unitary representation.

Analogues to Shiffrin and Schneider's procedure, I conducted a training experiment with chess novices. Therefore I replicated Experiment 4 (using the same 3x3 grids as stimuli), with just two changes. First, novices trained the S-R mapping for over 5000 trials in 5 sessions, and second, prime duration was reduced to 20 ms (same duration as in Experiment 1). In contrast to comparison of novices and experts in Experiment 1, elongating prime duration from 20 ms to 29 in Experiment 4 was sufficient to induce in novices weak response priming and strong perceptual priming. Although visibility ratings did not correlate with the perceptual priming effects, they were significantly above chance. Thus, the purpose of Experiment 5 was to find out whether response or perceptual priming effects emerge even when the primes are absolutely invisible and to elaborate whether lack of training with the chess material or the S-R mappings was responsible in Experiment 1 for preventing response priming.

4.2.1. Methods

(1) Participants

12 chess novices (aged 19-25, mean 21.0) participated in Experiment 5 that was separated in 5 individual sessions from Monday to Friday. Sessions lasted approximately 60 min, respectively, whereas the last fifth session lasted

approximately 75 min. All participants reported having normal or corrected-to-normal vision, and were not familiar with the purpose of the experiment.

(2) Apparatus and Stimuli

Apparatus and Stimuli were identical to Experiment 4, except that the vertical retraces of the VGA-Diagram were set to 100 Hz.

(3) Design and Procedure

Design and Procedure were identical to Experiment 4 except the following changes.

Each trial started with an empty 3 x 3 grid with a fixation cross in the middle presented for 400 ms. Premask, prime, postmask, and target were then presented. Premask and postmask, consisted of three different random dot patterns presented for 30, 20, and 20 ms. Prime duration was 20 ms; target duration was 250 ms.

There were five experimental sessions. One session consisted of 16 blocks of which each combination of prime (8) x target (4) was presented twice. Thus, 1024 trials were presented in each of the five sessions, resulting in a total of 5120 trials. The last session finished with the same detection task as in Experiment 1.

4.2.2. Results

(1) Response priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (1.9 %) were excluded. Mean RTs for correct responses and error rates for each combination of the factors prime type and response congruency are given in Table 5.

ANOVAs on RTs for correct responses as well as on error rates with the factors prime type and response congruency revealed neither significant effects for the main factors nor for their interaction, *p*s > .36.

A separate ANOVA on RTs with the factors session (1-5), prime type and response congruency, revealed a highly significant effect for the factor session, $F(4, 44) = 103.2$, $p < .001$, $\eta_p^2 = .90$, indicating that training was sufficient to speed up responses (1. session 593 ms, 2. session 519 ms, 3. session 497 ms, 4. session 476 ms, 5. session 476 ms). Neither the other single factors nor one of the two way interactions were significant, *ps* > .32.

The same ANOVA on error rates revealed no significant effects, *ps* > .30.

Table 5

Mean RTs (in Milliseconds) and Percentages of Errors for response priming and perceptual priming, for target and novel primes, for incongruent and congruent primes and the resulting congruency effects (in ms) in Experiment 5

	Response priming		Perceptual priming		
	Target primes	Novel primes	Target primes		Novel primes
Variables			Location	Form	Form
RTs					
Incongruent prime	511 (19.4)	510 (19.3)	514 (19.3)	512 (19.3)	511 (19.1)
Congruent prime	509 (19.9)	510 (19.4)	505 (20.0)	507 (19.9)	510 (19.7)
Congruency effect	1	0	10**	5**	1
Error rates					
Incongruent prime	4.3 (0.6)	4.5 (0.9)	4.7 (0.8)	4.3 (0.7)	4.5 (0.8)
Congruent prime	4.4 (0.8)	4.3 (0.7)	4.0 (0.7)	4.4 (0.8)	4.3 (0.8)
Congruency effect	0.1	0.2	0.7*	-0.2	0.2

Note. Corresponding standard errors are shown in parantheses. Discrepancies in the computed congruency effect result from rounding errors. RTs = reaction times.

* $p < .05$, ** $p < .01$, *** $p < .001$.

(2) Perceptual priming

For the analysis of perceptual priming effects, I separately analyzed target primes (for location and form effects) and novel primes (for form effects). Mean RTs for correct responses and error rates for each combination of the factors location congruency and form congruency for target primes and for the factor form congruency for novel primes are given in Table 5.

Target primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.0 %) were excluded. Averaged data across all participants are presented in Figure 12.

An ANOVA on RTs for correct responses to target primes with the factors location congruency and form congruency revealed significant main effects for location congruency, $F(1, 11) = 13.6$, $p < .01$, $\eta_p^2 = .55$, and form congruency, $F(1, 11) = 18.5$, $p < .01$, $\eta_p^2 = .63$. The interaction between location congruency and form congruency was not significant, $p > .22$. Participants responded faster when either the location or the form of the attacker was the same in prime and target diagram (514 ms different location vs. 505 ms same location; 512 different form vs. 507 same form).

The same ANOVA on error rates (see Figure 12) revealed a significant main effect for location congruency $F(1, 11) = 6.4$, $p < .05$, $\eta_p^2 = .37$, indicating that participants made more errors when the attacker's location in prime and target diagram was different (4.7 %) vs. same (4.1 %). The other factor and the interaction revealed no significant effects, *ps* > .58.

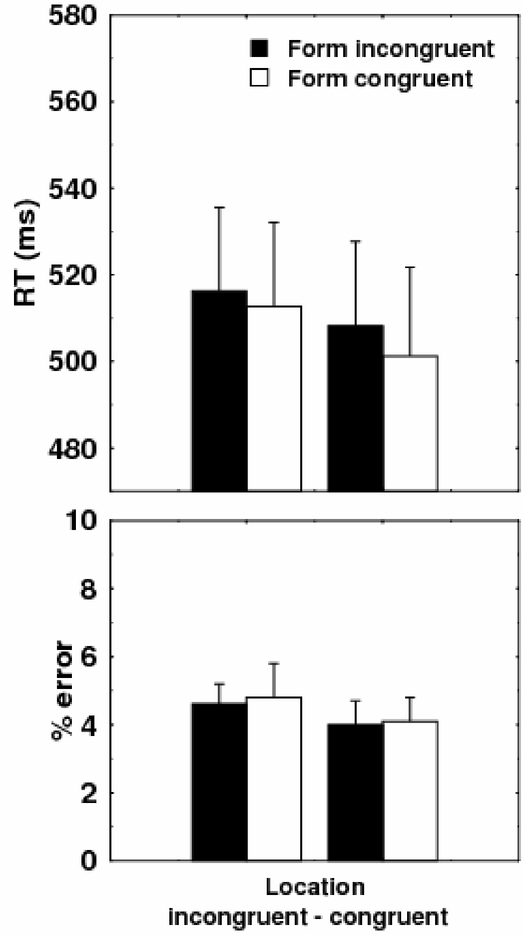

Figure 12. Novices mean RTs (upper panel) and error rates (lower panel) for target primes depending on perceptual congruency (location and form) in Experiment 5. Lines represent standard errors.

A separate ANOVA on RTs with the factors session (1-5), location congruency and form congruency, reveals significant main effects for all three factors. The factor session was again highly significant $F(4, 44) = 99.9$, $p < .001$, $\eta_p^2 = .90$, indicating that training was sufficient to speed up responses. Moreover, both perceptual effects did not interact significantly with this training effect, *ps* > .12.

The same ANOVA on error rates with the factors session (1-5), location congruency and form congruency, reveals a significant main effect only for location congruency, but not for session, $p > .36$. There was no significant interaction, *ps* > .18.

Novel primes. Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (1.9 %) were excluded. An ANOVA on RTs as well as on error rates for novel primes with the factor form revealed no significant effects for form congruency, *p*s > .39.

(3) Prime visibility

Participants' discrimination performance for check vs. non-check primes was $d' = .075$ and did not deviate significantly from zero, $t(11) = 1.36$, $p > .20$.

To test whether the priming effect is related to prime visibility, a priming index for the RT congruency effect was computed for each participant and each prime type as in Experiment 4. A subsequently performed linear regression analysis revealed a significant correlation between d' and the priming index for location priming $r = .578$, $F(1, 11) = 5.01$, $p < .05$, as well as for form priming $r = .845$, $F(1, 11) = 25.00$, $p < .001$, indicating that better visibility (individual d'-values reached from to -.24 to .38) causes higher perceptual priming effects. The intercept of the regression was larger than zero for location priming (intercept = 1.55, $t(11) = 3.22$, $p < .01$) as well as for form priming (intercept = .80, $t(11) = 5.33$, $p < .001$, indicating that significant perceptual priming effects are associated with *d′*-values of zero.

4.2.3. Discussion

In Experiment 5, novices were considerably faster than in Experiment 4 (502 ms vs. 604 ms) and made fewer errors because of the extensive training. Unconsciously presented chessboard configurations elicited perceptual location priming as well as perceptual form priming. As in Experiment 4, no perceptual form priming was observed when the attacker was presented on a novel (unexpected) square. In contrast to Experiment 4, however, in Experiment 5, the perceptual priming effects were numerically smaller (two to three times), response priming was totally eradicated, and the check situation in the prime diagram was not discriminated above chance. In the following I will discuss each of the results more closely.

First, training speeded up responses considerably. Already in the second session, chess novices reached a response time level that lies even beneath that of experts (519 ms vs. 529 ms in Experiment 1), although chess experts are normally faster than novices in deciding whether the king (or another piece) is attacked (Bilalić et al., 2011; Reingold, Charness, Pomplun, & Stampe, 2001; Saarliuoma, 1985). With all five sessions together, novices executed eight times more trials than experts in Experiment 1 or 4. Nevertheless, response priming effects were not observed in Experiment 5. Thus, solely training the S-R mapping (the two key responses to the four target diagrams) is not sufficient to elicit response priming. Therefore, this result is in line with studies on expertise, demonstrating that simple experience is not enough to develop expertise (Feltovich, Prietula, & Ericsson, 2006; Ericsson & Lehmann, 1996).

Additionally, it had been demonstrated that a short duration between prime presentation and target response is crucial for eliciting response priming effects, because subliminal priming effects have a short endurance (e.g. Greenwald, et al., 1996). However, the overall response times in Experiment 5 show (besides the percentile analyses in Experiment 1) that the already found difference between novices and experts with respect to response priming in Experiment 1 cannot be explained with different over all response times, because in the same subliminal check detection task, already at the end of the second session, chess novices responded even faster than chess experts in the same task without specific training.

Second, instead of response priming, I found small but significant perceptual priming effects of the stimulus features location and form which were independent from each other. Chess novices responded faster to the target diagram, when either the location or the form of the attacker was the same in the prime diagram and in the target diagram. This result is in line with studies reporting effects of perceptual location priming (e.g. Ivanoff & Klein, 2003; Jaskowski, van der Lubbe, Schlotterbeck, & Verleger, 2002; Lambert et al., 1999; McCormick, 1997; Mulckhuyse et al., 2007) or perceptual form priming (e.g. Bar & Biederman, 1998; Bodner & Dypvik, 2005; Bodner & Masson, 1997; Koechlin et al., 1999). However, the current finding extends these studies in two aspects. On the one hand, in Experiment 4 as well as in Experiment 5, I demonstrated perceptual location priming as well as perceptual form priming within the same experiment with bivalent stimuli (the attacker contains the location information as well as the form information). On the other hand, perceptual location priming and perceptual form priming were opposed to response priming. Thus, the results in Experiment 5 reveal that perceptual priming even dominates over response priming.

Third, this low level perceptual influence on stimulus processing may also account for different results regarding the current training with chess novices and the results of Shiffrin and Schneider (1977) who found a pop out effect after extensive practise (after about 2000 trials in a letter search task). Whereas in the current experiments a priming task was applied with successive presentation of a prime diagram and a target diagram in each trial, Shiffrin and Schneider (1977) used just one stimulus array in a trial. They presented target and distractor stimuli simultaneously and on separate locations. So, comparing Shiffrin and Schneider's study and Experiment 5, automatization in terms of training effects was established with different methods and operationalized with different criteria. On the one hand, it is conceivable that disturbing low level perceptual influences would even derive with letters when they are presented in advance as primes, what was not the case in Shiffrin and Schneider, 1977 (see Reuss, Pohl, & Kiesel, 2009, who found low level perceptual location and form priming with letter stimuli). On the other hand, it could be possible to induce with few thousand trials a pop out like effect for novices when they just have do discriminate different diagrams without a presented prime diagram in advance (see Gauthier & Tarr, 1997, who observed the acquisition of configural sensitivity to artifical nonface stimuli called “Greebles” after an average of 3240 trials).

Moreover, it is possible that the training was not sufficient to neutralize the quantitative as well as qualitative differences between novices and experts in chess perception. Qualitative differences between novices and experts in chess probably exists in kind of a distinct representation experts posses concerning chess diagrams, the form, and the relations of chess pieces. In contrast to experts who have spent plenty of time in studying and playing chess, novices have only played few chess games in their life and probably had no former experience with the presented chess diagrams. Thus, novices could not rely on distinct representations when responding to the chess diagrams. Concerning perceptual experience with chess diagrams, the typical form, and the relations of chess pieces, about five hour training in the experiment seems to be not enough to acquire an adequate perceptual distinctiveness. In studies about perceptual learning with novel “Greebles” objects, experts who are usually trained for 10 hours show configural sensitivity (Tarr, 2000; Williams, Gauthier, & Tarr, 1997). In contrast, in Shiffrin and Schneider’s (1997) study, the to be searched target letters (e.g. B, C, D, F, G, H, J, K, and J) are in our culture highly familiar and well trained already before the experiment, although they share perceptual features with the distractor letters (e.g. Q, R, S, T, V, W, X, Y, and Z) like a vertical line or a curve. So, despite perceptual similarities, different letters are clearly perceived as distinct identities. And as a result of a highly overlearned process (years of experience with letters and words from school to every day life) each single letter is perceived as the letter as a whole and not as a composition of different features like lines and curves. What had only to be learned to induce a pop out-like effect for the letters in the study by Shiffrin and Schneider (1997) was that different distinct identities (the letters) belonged in as much together as they afforded the same response.

Qualitative differences between novices and experts in chess may derive from the meaning that the presented chess diagrams have for the participants. In contrast to experts, for novices the task is rather artificial or unnatural when they have to respond to two diagrams with a left and to two other diagrams with a right key. To resolve this task, it was not necessary to imagine how the pieces may move, but participants could rather respond to the four diagrams according to a constant S-R mapping. On the one hand, it had been shown that not perceptual similarities but a common action which is afforded by different objects to reach a certain goal is crucial to build up a unitary representation (Brown, 1989; Hoffmann & Grosser, 1985/86; Rensch, 1968, cited after Klix, 1980). This common action is called functional equivalence. It is seen as a precondition to build up a unitary representation of these objects that is a distinct neuronal activation pattern. On first sight one might suggest that the common action in the check detection task is the left or right key press. However, in everyday life und in several experiments (Brown, 1989; Rensch, 1968, cited after Klix, 1980) the common action is the functional use of a tool or object. In chess the common action to the rook and knight in the presented check diagrams is the same key press because both gave check to the king (in the next move they could capture the king). So, the decisive difference between chess experts and novices may be that experts automatically extract the relation of the pieces that let them “feel” whether the King is in check or not. Even after training, novices may still do not respond according to the meaning of the diagram but just to the mere configuration of the pieces. It seems to be that for perceptualle different features to induce the acquisition of the concept of functional equivalence and to build up a unitary representation. However, as it had been shown that a left or right key press response can indeed lead to the acquisition of functional equivalence (Hoffmann & Grosser, 1985/86; Shiffrin & Schneider, 1977) it may be, that with the used stimuli 5000 trials are just not enough to build up a unitary representation and that novices will elicit response priming with more training.

Finally, in Experiment 4, I found perceptual priming effects with partly visible primes. Here in Experiment 5, the overall visibility measure did not differ significantly from zero. Nevertheless, the single features location and form produced significant but numerically smaller perceptual priming effects compared to Experiment 4. However, in Experiment 5, there was a positive correlation between visibility (overall *d’* value there was .075 ranging from individual *d’* values from -.24 to .38) and the size of the location as well as the form effect. Thus, it seems that the perceptual priming effects of location and from depend somewhat on visibility and that increasing visibility leads to increasing perceptual priming effects. In comparison to Experiment 4, the perceptual priming effects were substantially reduced (from 29 ms to 10 ms for location priming, from 22 ms to 5 ms for form priming). There are two mayor differences between the two experiments. First, the number of trials was octuplicated in Experiment 5. As a result, this training was sufficient to speed up responses substantially. So the question arises whether a ceiling effect was responsible for the reduction of the perceptual priming effects and the abolition of response priming. However, substantial response priming effects as well as perceptual priming effects have already been observed in several studies with even lower RT levels than in Experiment 5 (e.g. Ansorge et al., 2002; Breitmeyer & Hanif, 2008; Kunde, 2003; Ivanoff & Klein, 2003; Jaskowski et al., 2003; Mulckhuyse et al., 2007). Thus, it is unlikely that the increased number of trials is responsible for the different pattern of priming effects between Experiment 4 and 5. Second, the duration of the prime was reduced from 29 ms in Experiment 4 to 20 ms in Experiment 5, rendering the prime invisible which might have affected the priming impact. For example, Kunde and colleagues (2005; see Van Opstal, Reynvoet, & Verguts, 2005a, 2005b for a close discussion) found that increasing prime duration (from 43 ms to 72 ms) improves the prime detection rate (amounting from *d´* = .22 to .66 which is comparable to the *d´*-values in Experiment 4 and 5, respectively) and amplifies priming. With longer presentation time, there was not only a numerical increase in the priming effect but also a cross notation transfer so that, although only Arabic digits were presented as targets, also number words were effective as primes. Within the same line, Klauer and colleagues (2007; Exp. 3) demonstrated that congruency effects are a function of prime duration and prime novelty. They administered a gender word classification task, presenting primes for different durations (25 ms vs. 42 ms) and using novel primes as well as target primes.

Priming effects increased with the longer presentation time and even spread to novel primes, although novel primes could not be discriminated above chance. Furthermore in an ERP (event-related brain potential)-study by Holcomb, Reder, Misra, and Grainger (2005; Exp. 2) longer prime durations in a semantic classification task produced larger N400s which were also positively correlated with prime visibility. So far the influence of prime duration or of the stimulus onset asynchrony (SOA, the interval between prime and target onset) on response activation as well as prime visibility has been at least studied systematically in two studies: Van den Bussche and colleagues (2007) applied a masked priming experiment with the classical “smaller or larger than 5”-task and a variety of almost 30 different prime durations (from 5 ms to 90 ms). As a result, priming effects increased in a linear manner with longer prime durations. The visibility of the primes also increased with longer prime durations, but not as continuously as the priming effects. Vorberg and colleagues (2003) manipulated SOAs of matacontrasted arrows and found that visual perception and priming follows a different time course. Stronger priming effects were not associated with better visibility of the stimuli. In one condition also the reverse was true – the amount of priming increased while the recognition performance decreased. However, (as it can be seen in their figure 3) longer prime duration always led to stronger priming effects. Concerning the difference of the results between Experiment 4 and 5, it seems to be that in Experiment 5 with only 20 ms prime duration, there was not enough prime induced activation for the integration of the two perceptual features location and form and to enable novices to show response priming. On the contrary in Experiment 4, the longer presented prime (29 ms) allowed novices initial feature integration whereas at the same time the perceptual impact of the single features (location and form) also increased. As for now a preliminary hypotheses is, that with unfamiliar material and untrained cognitive operations more time and / or activation is needed for feature integration and response triggering. Therefore, it is conceivable that due to the longer presentation time and better visibility (mean *d´*-value in Experiment 5 was .075, in Experiment 4 it was .252) both the prime induced response activation and the low-level impact of perceptual features was larger in Experiment 4 than in Experiment 5, paving the way for response priming as well as enlarging perceptual priming effects.

4.3. Experiment 6: Location priming of unexpected form

Experiment 4 and 5 showed that there was no perceptual form priming effect for locations when the chess piece occurred at a location that never contained chess pieces in the target diagrams. So, a necessary precondition for the form priming effect to occur is that attention is directed in advance to the possible location where the critical stimulus is presented. What we do not know so far is whether the same holds true the other way around for the location priming effect. Does location priming only occur if the forms (i. e. the chess pieces) are expected, especially, when the accomplishment of the instructed task makes it necessary to consider the form of the stimulus at first? Thus, Experiment 6 was designed to find out how robust the perceptual location priming effect and how important form expectation is. Moreover, I wanted to find out whether it is even possible to elicit response priming with the present design (a check detection task with 3x3 chess diagrams). I therefore applied a task that does no longer require the integration of two features in an XOR-manner.

Stimuli were again 3x3 chessboards that either diagrammed a checking or a nonchecking configuration. A black king was always presented in the upper left corner. The white attacker in the four target diagrams was always a rook, presented on one of four different locations (upper right corner, middle right square, lower middle square and lower left square). Again, participants carried out one response upon identifying a checking position and another response upon identifying a nonchecking configuration. Two target diagrams displayed a checking configuration (see Figure 13, panels A and C) whereas two target diagrams entailed a nonchecking configuration (panels B and D). Now, to decide whether the king is in check or not, it was sufficient to consider the location were the rook was presented.

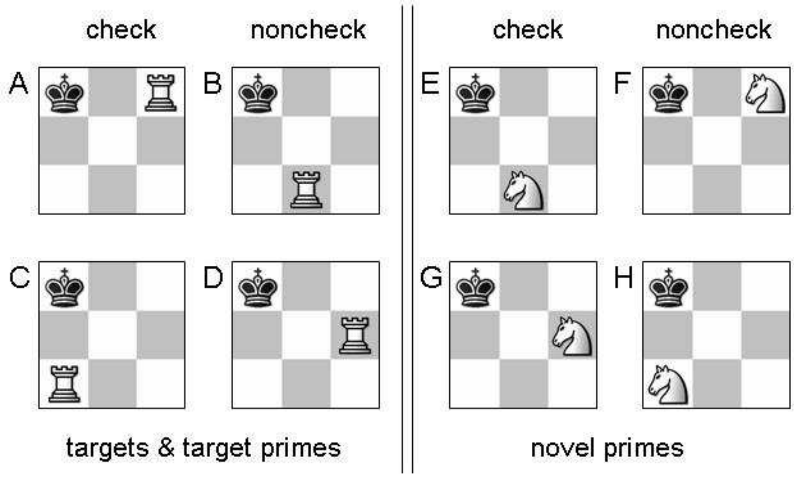

Figure 13. Stimulus set used in Experiment 6: The 3 x 3 grids either diagrammed a checking configuration (panels A, C, E, and G) or a nonchecking configuration (panels B, D, F, and H). They were either presented as targets as well as primes (panels A, B, C, and D) or only as primes (panels E, F, G, and H).

Before each target diagram, again a prime diagram was presented. The same four diagrams with the rook located on four different squares were used as primes (target primes). In addition, four diagrams were used as primes in which a knight was located on the same four different squares (novel primes). Two of these novel prime diagrams entailed a checking configuration (panels E and G) and two of these novel prime diagrams contained a nonchecking configuration (panels F and H). Thus, on the one hand, responses for prime and target diagram are congruent when both prime and target diagram depict a checking or nonchecking situation (Figure 13, for target primes A-A, B-B, C-C, D-D, A-C, C-A, B-D, D-B; for novel primes E-A, E-C, G-A, G-C, F-B, F-D, H-B, H-D), otherwise they are incongruent (for target primes A-B, A-D, B-A, B-C, C-B, C-D, D-A, D-C; for novel primes E-B, E-D, F-A, F-C, G-B, G-D, H-A, H-C). On the other hand, the location of the attacker in prime and target diagram is congruent when the pieces are diagrammed on the same square (for target primes A-A, B-B, C-C, D-D; for novel primes E-B, F-A, G-D, H-C) and incongruent when the pieces are diagrammed on two different squares (for target primes A-B, A-C, A-D, B-A, B-C, B-D, C-A, C-B, C-D, D-A, D-B, D-C; for novel primes E-A, E-C, E-D, F-B, F-C, F-D, G-A, G-B, G-C, H-A, H-B, H-D). Thus with target primes, response congruent trials are either location congruent (the identical prime-target repetitions (A-A, B-B, C-C, D-D) or location incongruent (A-C, C-A, B-D, D-B). However, for novel primes, location congruency is always associated with response incongruency as well as with form incongruency (as the attacker is always a rook in the target diagram and a knight in the prime diagram). Moreover, for target primes the form of the attacker is always congruent because a rook is presented in the prime diagrams as well as in the target diagrams. For novel primes, the form of the attacker is always incongruent because a knight is presented in the prime diagrams, whereas a rook is presented in the target diagrams.

Response priming in Experiment 6 would indicate that in Experiment 5 and in Experiment 1 the special XOR-design together with the necessary integration of two features was responsible for eliminating response priming in novices. On the other hand, no response priming in Experiment 6 would stress the disturbing impact of low level features. Concerning perceptual priming, it is critical whether location priming even arises when the form of the attacker in the prime diagram is different (novel prime) than in the expected target diagram and whether a potential location priming effect for the unexpected form in novel primes is smaller than for target primes. Moreover, faster responses for target primes (a sequence of rook – rook diagrams within a trial) than for novel primes (a sequence of knight – rook diagram within a trial) would indicate a form priming effect although the form of the attacker is no longer response relevant.

4.3.1. Methods

(1) Participants

16 chess novices (aged 20-50, mean 26.6) participated each in an individual session of approximately 55 min. All participants declared having normal or corrected-to-normal vision and were not familiar with the purpose of the experiment.

(2) Apparatus and Stimuli

Apparatus and Stimuli were identical to Experiment 5 except for the following changes. From the eight 3x3 chessboards, targets were four grids with a rook located on one of four different positions (upper right, middle right, lower left, and lower middle square). Again, all eight chessboards from Experiment 1 (rook or knight located in the upper right, middle right, lower left, or lower middle square) were used as primes.

(3) Design and Procedure

Design and Procedure were identical to Experiment 5 except for the following changes: The experiment consisted of 10 blocks in which each combination of prime (8) x target (4) was presented twice in random order (640 trials altogether). The experiment finished with a detection task with 128 identical trials.

4.3.2. Results

(1) Response priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (1.7 %) were excluded. Mean RTs for correct responses and error rates for each combination of the factors prime type (target primes and novel primes) and response congruency (congruent and incongruent) are given in Table 6.

An ANOVA on RTs for correct responses with the factors prime type and response congruency revealed neither significant effects for the main factors nor for their interaction, *p*s > .17. The same ANOVA on error rates revealed a marginally significant interaction prime type x response congruency, $F(1, 15) = 3.2$, $p < .09$, $\eta_p^2 = .18$, and a marginally significant effect for the factor prime type, $F(1, 15) = 3.4$, $p < .09$, $\eta_p^2 = .18$ The factor response congruency was not significant, $p > .11$. Planned t-Tests revealed that participants tended to make more errors for incongruent (6.1 %) compared to congruent (4.5 %) novel primes $t(15) = 2.02$, *p* <

.05. There was no difference in error rates between congruent and incongruent target primes, $p > .95$.

Table 6

Mean RTs (in Milliseconds) and Percentages of Errors for response priming and perceptual location priming, for target and novel primes, for incongruent and congruent primes and the resulting congruency effects (in ms) in Experiment 6

	Response priming		Perceptual location priming	
	Target primes	Novel primes	Target primes	Novel primes
RTs				
Incongruent prime	473 (15.2)	477 (15.6)	477 (14.2)	479 (15.4)
Congruent prime	475 (14.8)	477 (16.5)	466 (17.4)	470 (17.4)
Congruency effect	-2	0	11*	9*
Error rates				
Incongruent prime	4.4 (0.8)	6.1 (0.8)	4.4 (0.6)	5.3 (0.7)
Congruent prime	4.5 (0.6)	4.5 (0.6)	4.4 (0.8)	5.2 (0.8)
Congruency effect	0	1.6*	0	0.2

Note. Corresponding standard errors are shown in parantheses. Discrepancies in the computed congruency effect result from rounding errors. RTs = reaction times.

* $p < .05$.

(2) Perceptual priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (1.7 %) were excluded. Averaged data across all participants are presented in Figure 14.

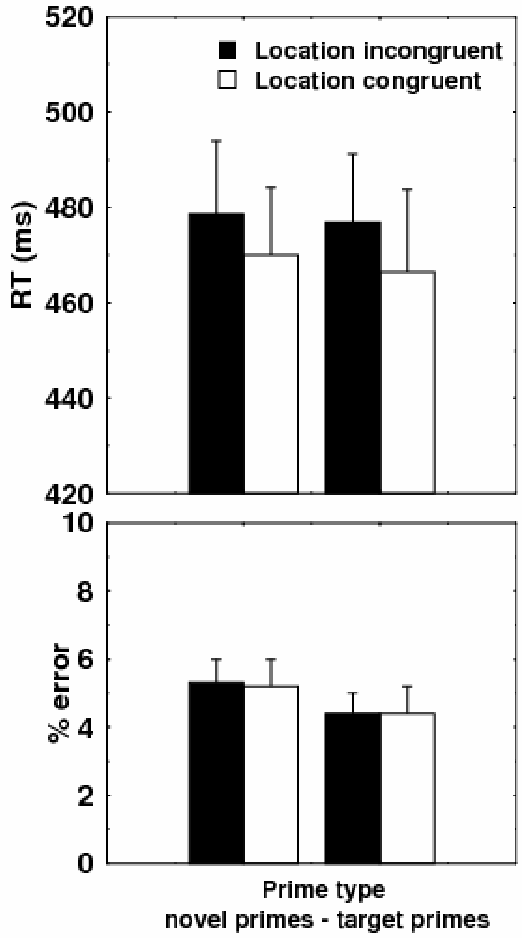

Figure 14. Novices mean RTs (upper panel) and error rates (lower panel) depending on prime type and perceptual location congruency in Experiment 6. Lines represent standard errors.

An ANOVA for correct responses with the factors prime type and location congruency revealed a significant main effect for the factor location congruency, $F(1, 15) = 5.4$, $p < .05$, $\eta_p^2 = .27$. Neither the factor prime type nor the interaction of both factors was significant, *ps* > .26. Participants responded faster when the attacker was presented on the same square (468 ms) in prime and target diagram compared to different squares (478 ms), irrespective of whether the same piece (a rook) or a different piece (a knight) was presented in the prime diagrams as in the target diagrams.

The same ANOVA on error rates revealed no significant effects, ps > .14.

(3) Prime visibility

Participants' discrimination performance for check vs. non-check primes was *d´* = -.037 and did not deviate significantly from zero, $t(15) = -.77$, $p > .45$.

To test whether the priming effect is related to prime visibility, a priming index for the RT congruency effect was computed for each participant. A subsequently performed linear regression analysis revealed no significant correlation between *d'* and the priming index for location priming $r = .011$, $F(1, 15) = .02$, $p > .96$. The intercept of the regression was larger than zero (intercept = 2.43, $t(15) = 2.23$, $p < .05$), indicating that significant perceptual location priming effects are associated with *d'*-values of zero.

4.3.3. Discussion

In Experiment 6, neither reliable response priming nor form priming was observed. Instead, perceptual location priming was again present and even transferred from a different form between prime and target stimuli. In the prime diagrams not only white rooks but also white knights elicited significant perceptual location priming that did not differ in size from each other. Numerically the location priming effect was somewhat lager for rook-rook trials (11 ms) than for knight-rook trials (9 ms), but this difference was not statistically reliable ($F(1, 15). = 1.3$, $p > .26$, $\eta_p^2 = .08$). The absence of response priming as well as form priming, and the nature of the observed location priming effect lead to four conclusions.

First, the form of the attacker in the prime diagram is only processed when it is task relevant. The form priming effect in Experiment 4 and 5 indicates that novices are able to discriminate the form of different chess pieces unconsciously. Whereas in Experiment 4 and 5, perceptual form priming only occurred on expected locations of the attacker, now in Experiment 6 the attacker in the presented target diagram was always a rook. Thus, the feature form was no longer response-relevant. As a result form congruency of the attacker between prime and target diagram did not influence responding. In Experiment 6, concrete form expectation was neither a necessary precondition for perceptual location priming nor contributed significantly to the size of the location priming effect.

Second, participants responded mainly according to the location of the attacker. It is conceivable that participants' response strategies changed in the course of the experiments. In order to carry out the right response, initially it was necessary to apply the chess rules and therefore to consider the location as well as the form of the attacker. However, it is likely that very soon the participants only considered the location of the attacker which alone was sufficient to determine the required response (upper right square and lower left square for one response; middle right square and upper middle square for the other response) and that the form of the attacker became an irrelevant feature. It is possible that instead of a white rook any white spot - dependent on the square where it is located – had become an appropriate release condition for the necessary response and also would have gained the power to catch attention unconsciously leading to perceptual location priming.

Third, this result underlines the central importance of (directing attention to) the feature location in visual perception even for unconscious processing and is therefore in line with observations made with supraliminally stimuli. It has already been shown that a perceptual location cuing effect is stronger and more robust than a perceptual form cuing effect (e.g. Lambert & Hockey, 1986). Treisman and Gelade (1980) already stated in their feature-integration theory of attention that “focal attention provides the “glue” which integrates the initially separable features into unitary objects” (p. 98; see also Treisman, 1996). The predominant role of location processing is also included in a review and integrated in search model by Wolfe (1994). Additionally, earlier and sometimes larger ERP effects are elicited when attention is directed to stimulus’ location compared to other features like colour (Eimer, 1995), movement direction (Anllo-Vento & Hillyard, 1996), or shape

(Harter, Aine, & Schroeder, 1982). Whereas for supraliminal location processing, in the visual ERPs early P1 and N1 components are already modulated (Anllo-Vento & Hillyard, 1996), motor activation through subliminal stimuli as indexed by LRPs usually starts later, about 200 ms after prime onset (Eimer & Schlaghecken, 1998; Leuthold & Kopp, 1998). The results of Experiment 4-6 are in line with these findings and conclusions, showing that privileged location processing also applies for unconsciously presented stimuli.

Furthermore, contrary to Experiment 4 and 5, in Experiment 6 there was neither an XOR-task to accomplish nor was it necessary to integrate two different features of the attacker in order to select the correct response. Nonetheless, I did not observe reliable response priming. The low level influence of perceptual location priming alone was strong enough to eliminate response priming. The location of the attacker in the prime diagram attracted attention. As a result, responses to the target diagram were faster when the location of the attacker was the same. Otherwise, additional time was needed to reallocate attention from the prime to the target diagram. Although only one feature were to discriminate (the location of the attacker), novices were unable to build up S-R links between the four different target diagrams and the two response alternatives that are strong enough to overcome the powerful influence of perceptual location priming.

4.4. Experiment 7: Location priming of unexpected colour

Experiment 4-6 provided strong evidence that when directly contrasted with response priming it is nevertheless possible to elicit perceptual location priming even when the form of the critical feature (the kind of the attacking chess piece) differs between prime and target. However, the perceptual differences between a white rook and a white knight are not quite big. Both are chess pieces representing a potential threat to the black king and therefore included in participants attentional set (at least in Experiment 4 and 5). So, I wanted to find out how robust the observed location priming effect really is. Especially I was interested to examine whether location priming survives a more substantial change between prime and target appearance when again contrasted with response priming.

Some studies that investigated exogenous cuing and attentional capture with supraliminally presented stimuli, showed that the onset of totally irrelevant and perceptually different stimuli is sufficient to attract attention and therefore to speed up processing of target stimuli appearing at the cued location (e.g. Jonides, 1981; Theeuwes, 1994; Yantis, 1993). For example, when participants had to indicate whether a white T is presented among white Ls, red and green singletons attracted attention although their colour was not only irrelevant but also not searched for in the task (Turatto & Galfano, 2001). To what extend do these findings apply for subliminal stimuli?

When being the response defining feature, different colour primes which were completely masked activated a motor response (Breitmeyer, Ro, & Singhal, 2004; Schmidt, 2002) or elicited a spatial cuing effect as well as triggered an ERP correlate indicating attentional capture (Ansorge et al., 2009). However, when colour was an irrelevant feature, top down influences were decisive and for masked primes presented in target dissimilar colour, location priming was reduced (Ansorge & Heumann, 2006) or eliminated (Ansorge & Heumann, 2003; Ansorge & Neumann, 2005).

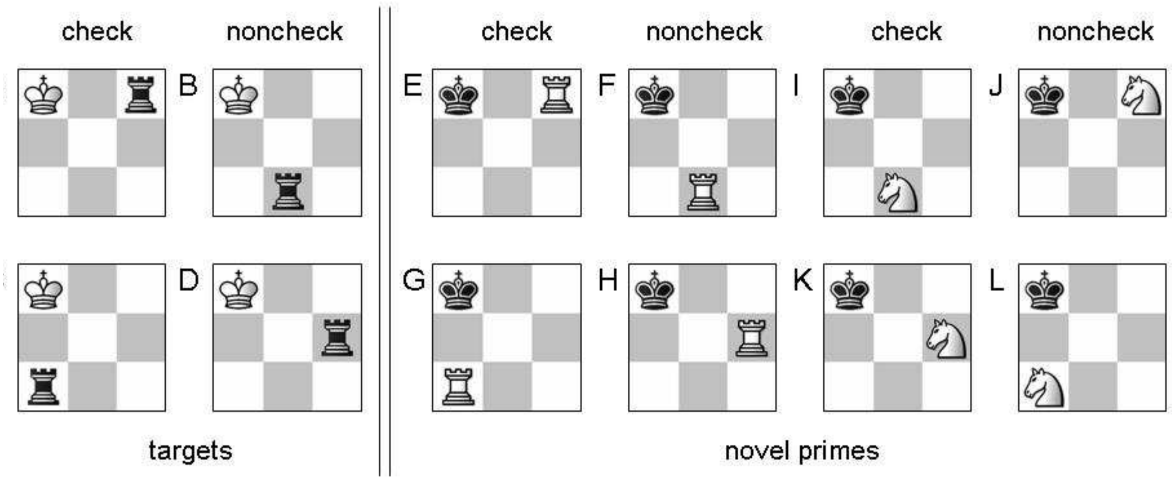

Figure 15. Stimulus set used in Experiment 7: The 3 x 3 grids either diagrammed a checking configuration (panels A, C, E, G, I, and K) or a nonchecking configuration (panels B, D, F and H, J, and L). They were either presented as targets as well as primes (panels A, B, C, and D) or only as primes (panels E, F, G, H, I, J, K, and L).

In order to increase the difference between the prime and target stimuli in Experiment 7 the colour of the pieces in the target diagram was changed. Now, the king (located on the upper left square) was always white, whereas the rook was always black in the four target diagrams (located either on the upper right, middle right, lower left, or lower middle square), retaining the same check/noncheck relations and response mapping as in Experiment 6. As primes the same eight diagrams as in Experiment 6 where the king was always black and the attacker – either rook or knight – was always white (see Figure 15) were used.

4.4.1. Methods

(1) Participants

22 chess novices (aged 16-31, mean 23.0) participated each in an individual session of approximately 55 min. All participants declared having normal or corrected-to-normal vision and were not familiar with the purpose of the experiment.

(2) Apparatus and Stimuli

Apparatus and stimuli were identical to Experiment 6 except for the following changes. The colour of the pieces (king and attacker) in the target diagram changed. In the target diagrams, there were four 3x3 chessboards were now a white king was always located on the upper left square and a black rook was located on the upper right, the middle right, the lower left, or lower middle square. As primes we used the same eight diagrams as in Experiment 6 (a black king that was always located on the upper left square and a white attacker - rook or knight located in the upper right, middle right, lower left, or lower middle square).

(3) Design and Procedure

Design and Procedure were identical to Experiment 6.

4.4.2. Results

(1) Response priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (1.9 %) were excluded. Mean RTs for correct responses and error rates for each combination of the factors prime type and response congruency are given in Table 7.

An ANOVA on RTs for correct responses with the factors novelty of prime type and response congruency revealed a significant main effect for response congruency, $F(1, 21) = 5.2$, $p < .05$, $\eta_p^2 = .20$. Neither the factor prime type nor the interaction prime type x response congruency was significant, *p*s > .54. The same ANOVA on error rates revealed no significant effects *p*s > .76.

On average, participants responded faster for congruent than for incongruent trials. However, removing prime-target pairs were the location oft the attacker is the same in prime and target diagram (E-A, F-B, G-C, H-D, I-B, J-A, K-D, L-C, see Figure 15) which confounds response priming and perceptual location priming, eliminates the response congruency effect. A subsequent ANOVA for RTs with the same factors revealed no significant effects, *ps* > .47.

Table 7

Mean RTs (in Milliseconds) and Percentages of Errors for response priming and perceptual location priming, for target and novel primes, for incongruent and congruent primes and the resulting congruency effects (in ms) in Experiment 7

	Response priming		Perceptual location priming	
	Target primes	Novel primes	Novel colour	Novel colour and form
RTs				
Incongruent prime	462 (9.3)	462 (9.4)	461 (9.3)	462 (8.9)
Congruent prime	458 (9.1)	460 (9.0)	456 (9.5)	457 (10.0)
Congruency effect	3	2	5*	5*
Error rates				
Incongruent prime	6.8 (1.1)	7.0 (1.3)	7.0 (1.0)	7.1 (1.3)
Congruent prime	6.9 (1.0)	6.8 (1.4)	6.4 (1.2)	6.3 (1.6)
Congruency effect	1	1	0.6	0.8

Note. Corresponding standard errors are shown in parantheses. Discrepancies in the computed congruency effect result from rounding errors. RTs = reaction times. * $p < .05$.

(2) Perceptual priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.0 %) were excluded. Averaged data across all participants are presented in Figure 16.

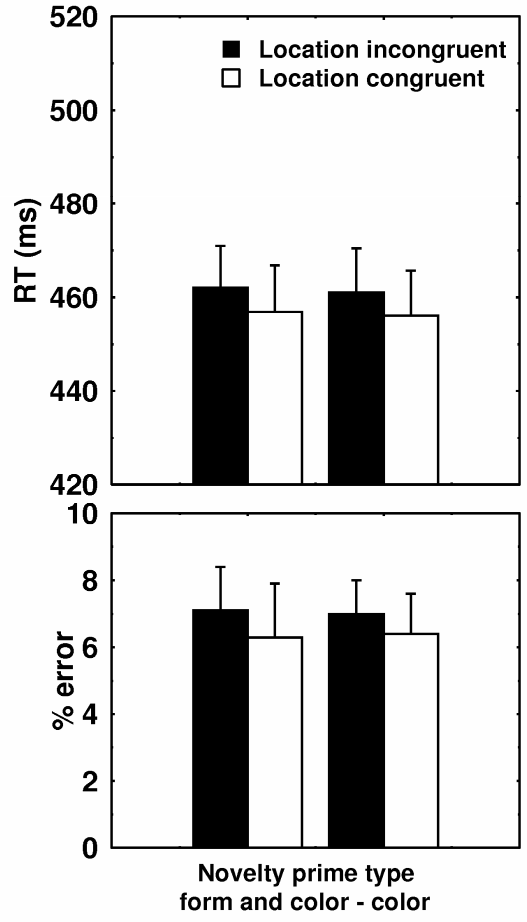

Figure 16. Novices mean RTs (upper panel) and error rates (lower panel) depending on novelty prime type and perceptual location congruency in Experiment 4. Lines represent standard errors.

An ANOVA for correct responses with the factors prime type and location congruency revealed a significant main effect for the factor location congruency, $F(1, 21) = 5.9$, $p < .05$, $\eta_p^2 = .22$. Neither the other factor novelty of prime type nor the interaction of both factors was significant, *ps* > .68. Thus, participants responded faster when in prime and target diagram the attacker was presented on the same square (456 ms) compared to different squares (462 ms), irrespective whether the same piece (a rook) or a different piece (a knight) as in the target chessboards was presented in the prime chessboards.

The same ANOVA on error rates revealed no significant effects, ps > .12.

(3) Prime visibility

Participants' discrimination performance for check vs. non-check primes was *d´* = .035 and did not deviate significantly from zero, *t*(21) = .84, *p* > .40.

To test whether the priming effect is related to prime visibility, a priming index for the RT congruency effect was computed for each participant and for response priming as well as perceptual priming. A subsequently performed linear regression analysis revealed no significant correlation between *d′* and the priming index for response priming *r* = .001, *F*(1, 21) = .00, *p* > .99. The intercept of the regression was marginally significant (intercept = .58, *t*(21) = 2.04, *p* < .06), indicating that priming effects are associated with *d′*-values of zero.

The same linear regression analysis revealed no significant correlation between *d′* and the priming index for location priming *r* = .285, *F*(1, 21) = 1.76, *p* > .19, while the intercept of the regression was larger than zero (intercept = 1.30, *t*(21) = 3.41, *p* < .05), indicating that significant perceptual priming effects are associated with *d′*-values of zero.

4.4.3. Discussion

Perceputal location priming contrasted with response priming survived a colour change. Whereas participants responded to black rooks in the target diagram, presenting the attacker in the prime diagram in another colour (white) nevertheless elicited perceptual location priming. Again, as in Experiment 6, in the current Experiment 7, presenting the attacker in another form (a knight in the prime diagram instead a rook in the target diagram) did not influence location priming (the location priming effect amounted 5 ms for prime diagrams with novel form of the attacker and for prime diagrams were the attacker was the same as in the target diagram, respectively). However compared to the results of Experiment 6, the perceptual location priming effect in Experiment 7 was substantially reduced (from 10 ms to 5 ms).

The location priming effect, I observed throughout experiments 4-7, may also reconcile as well as supplement divergent findings concerning exogenous cuing with masked cues. In replicating and extending McCormicks (1997) study who was able to elicited unconscious exogenous cuing, Ivanoff and Klein (2003) demonstrated that the instruction to report the cue at the end of each trial may lead to an attentional control setting (see Folk et al., 1992) which can be crucial for the impact of a cue. Participants' task was to press a single response key when a black filled target circle was presented and to do nothing when instead a grey filled circle appeared. The target could appear 4.9 cm left or right from a fixation cross. Before the target, an unpredictive cue (a hollow circle) was presented 4.5 cm from fixation. When cue awareness was measured trial-by-trial, Ivanoff and Klein found a facilitation effect for masked cues as in McCormicks study using a comparable SOA length (105 ms SOA in Invanoff & Klein, 2003; 80 ms SOA in McCormick, 1997). However, when no cue report was required, masked cues were ineffective. As a result of the instruction to report the cue, attention is directed to the cued location enhancing the strength of the cue, because participants maintain their attention to the cue in order to be able to detect the cue and to report it afterwards. Referring to the uncertainty principle in quantum physics, Invanoff and Klein (2003) concluded that “the temporal dynamics or magnitude of exogenous attention is altered when awareness of the cues is assessed” (p. 38). Yet, with a slightly different design, Mulckhuyse and colleagues (2007) observed a subliminal exogenous cuing effect with a post experimental instead of a trial-by-trial cue report task. In their study, cuing was accomplished through the advanced appearance of one of three placeholders (grey filled circles) left or right from central fixation. The target appeared with a 16 ms SOA and was a small black dot that was presented either in the middle of the left or the right placeholder. As soon as the target was seen, a single response key had to be pressed, whereas when no target was presented, response withholding was demanded. Responses were faster when the target appeared at the cued compared to the uncued location, although the participants were unable to detect the cue. In explaining the different results compared with Ivanoff and Klein’s study (2003), Mulckhuyse and colleagues (2007) pointed out that they used a relatively short SOA and that the target was presented immediately after the cue. Following Ivanoff and Klein (2003) and referring to what had already been observed with supraliminal cues (Theeuwes, Atchley, & Kramer, 2000), Mulckhuyse and collagures concluded that attention disengages rapidly from the subliminal cued location when task irrelevant cues are used. Therefore, a successive and rapid presentation of cue and target are seen as a necessary precondition to induce a facilitation effect with task irrelevant subliminal cues. Inline with Ivanoff and Klein's (2003) and Mulckhuyse and collagures (2007) studies, in the present experiments I found a stable subliminal location priming effect with an SOA of 101 ms (Experiment 4) and 90 ms (Experiment 5-7), with masks between prime and target, and without a trial-by-trial assessment of prime visibility. This clearly confirms McCormicks initial conclusion that (exogenous) "orienting attention without awareness" (McCormick, 1997, p. 168) is possible. However, some remarks have to be made. First, in contrast to the studies mentioned above, in the present experiments, location was not varied only orthogonally but also diagonally. So, the attacker in the target diagram was located either on the upper right or the lower middle square (Experiment 4 and 5) or that the attacker in the target diagram was presented on one of four different squares (Experiment 6 and 7). Second, the distances between the possible locations were smaller in all four experiments than in the studies by Ivanoff and Klein (2003), McCormick (1997), or Mulckhuyse and colleagues (2007), as a square on the chess diagram measured only 15 mm, so that the maximum distance between the square where the attacker was located in the prime and target diagram is 42.4 mm (measured between the middle point of the upper right and the lower left square). Third, because the location of the attacker in the prime diagram was unpredictive for the location of the attacker in the target diagram (Ivanoff & Klein, 2003, as well as Mulckhuyse et al., 2007, used unpredictive cues), the location in the prime diagram had only a validity of 25 % in Experiment 4-7. Fourth, the findings of Ansorge and Heumann (2003, 2006) and Ansorge and colleagues (2002) suggest that it is crucial whether the cue is task relevant and therefore meets top down expectations or not. Thus, it is possible, that the observed location effects with target dissimilar cues by Ivanoff and Klein (2003) as well as Mulckhuyse and colleagues (2007) are due the fact that only a single response was necessary so that any abrupt onset constituted a sufficient response criterion. In Experiment 4-7 chess pieces are certainly task relevant as well, but for the check detection task the colour of the pieces - which was changed in Experiment 7 - is crucial. So, the decrease of the size of the location priming effect from Experiment 6 to Experiment 7 underlines the importance of top down influences even for bottom up derived perceptual priming. However, the observed location priming effect in Experiment 7 was strong enough to survive a form as well a concomitantly colour change and therefore even occurred when task relevance was considerably reduced.

4.5. Experiment 8: Redundancy of location and form

The previous experiments (4-7) demonstrated strong location priming effects that alone were even sufficient to eradicate response priming (Experiment 6) and that survived changes in form (Experiment 5) as well as in colour (Experiment 7). Form priming on the other hand, elicited smaller effects and was only present on expected locations. However, the perceptual influences of location and form priming were not directly compared, yet. Therefore, Experiment 8 was conducted to create a condition in which location and form priming are present at the same time, while both types of priming facilitate different responses. Furthermore, the experimental design should provide a condition which additionally favours form priming.

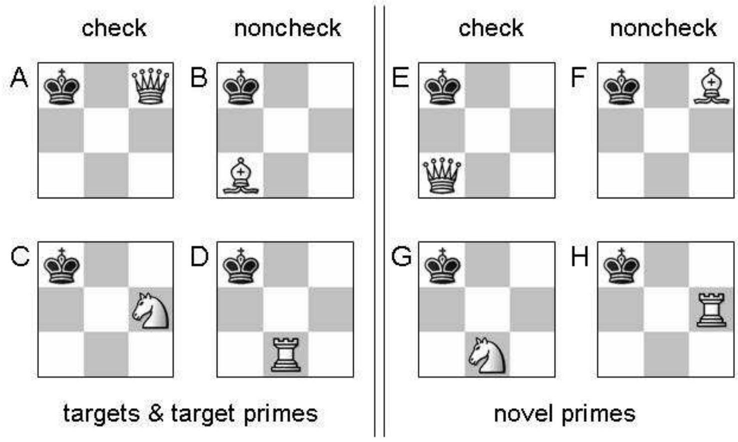

Figure 17. Stimulus set used in Experiment 8: 3 x 3 grids either diagrammed a checking configuration (panels A, C, E, and G) or a nonchecking configuration (panels B, D, F, and H).

Stimuli in Experiment 8 were again 3x3 chessboards which either diagrammed a checking or a nonchecking configuration. A black king was always presented in the upper left corner. Four diagrams where four different white attackers were located on four different squares (see Figure 17) were presented as targets and target primes: queen on upper right square (Panel A), knight on middle right square, (Panel C) rook on lower middle square (Panel D), and bishop on lower left square (Panel B). Additionally four different diagrams were presented as primes. On these novel primes, again the same four different attackers were used. For this reason the same squares as in the target diagrams were occupied by the attackers, however, in the prime diagram each attacker was located at another square than in the target diagram: queen on lower left square (Panel E), knight on lower middle square (Panel G), rook on middle right square (Panel H), and bishop on upper right square (F). Again, participants carried out one response upon identifying a checking position and another response upon identifying a nonchecking configuration. Two target diagrams diagrammed a checking configuration (see Figure 17, panels A and C) whereas two target diagrams entailed a nonchecking configuration (panels B and D). In order to decide whether the king is in check or not initially, it was necessary to consider the form of the attacker. However in Experiment 8, form and location are redundant features because each attacker was always located at a certain square. Queen and knight (Panels A and C) gave check to the king, whereas bishop and rook gave no check to the king (Panels B and D). The same holds true for the novel prime diagrams, where queen and knight (Panels E and G) also gave check to the king, whereas bishop and rook also gave no check to the king (Panels F and H). Thus, concerning target primes, response congruence is either connected to location as well as form congruence (Figure 17, A-A, B-B, C-C, D-D) or form as well as location incongruence (A-C, C-A, B-D, D-B), whereas response incongruence is always associated with form as well as location incongruence (A-B, A-D, C-B, C-D, B-A, B-C, D-A, D-C). However, of main interest for the purpose of the present experiment is the setting for novel primes. Here, response congruence is always connected to location incongruence (A-F, A-H, C-F, C-H, B-E, B-G, D-E, D-G), whereas half of these trials are additionally form congruent (A-E, C-G, B-F, D-H). Incongruent responses on the other hand are always related to form incongruence (A-F, A-H, C-F, C-H, B-E, B-G, D-E, D-G), whereas half of these trials are additionally location congruent (A-F, D-H, B-E, D-G).

I expect to find response priming for target primes, because of the converging influences of response congruence, location congruence and form congruence. For novel primes, response priming would indicate that form priming is stronger than location priming when the former is connected to response congruence, whereas a reversed response priming effect would indicate that the impact of location congruence dominates the impact of form congruence. Additionally, it is again possible to analyse separately whether perceptual location priming or perceptual form priming influenced responding.

4.5.1. Method

(1) Participants

17 chess novices (aged 19-43, mean 22.1) that had not taken part in one of the former experiments participated each in an individual session of approximately 55 min. All participants reported having normal or corrected-to-normal vision, and were not familiar with the purpose of the experiment.

(2) Apparatus and stimuli

Apparatus in Experiment 8 was identical to Experiment 7. Stimuli were eight pictures of minimized 3x3 chessboards extending 45 x 45 mm. Four 3x3 chessboards were used as targets and four different 3x3 chessboards were used as novel primes. In all eight diagrams, a black king was always located in the upper middle square (see Figure 17). Four diagrams were used as targets: Four different white pieces were used as attacker, each located on a certain square in the target diagrams – queen on upper right square, knight, on middle right square, rook on lower middle square and bishop on lower left square. These four chessboards served also as primes. Additionally there were four further novel diagrams used as primes were the four pieces were located on another square – queen on lower left square, knight on lower middle square, rook on middle right square, and bishop on upper right square. Whereas in all diagrams, the queen and the knight are giving check to the king, rook and bishop are never giving check to the king. Masks were random dot patterns extending 80 x 80 mm.

(3) Design and procedere

In Experiment 8, participants were instructed to indicate whether the target diagrammed a checking or a nonchecking configuration by pressing a left or right key. Experiment 8 was similar to Experiment 4 except the following: The experiment consisted of 10 blocks of which each combination of prime (8) x target (4) was presented two times. After the last session, participants were fully informed about the structure of the prime stimuli and were then presented with 128 trials for which they were to discriminate whether the prime diagrammed a checking or a nonchecking configuration.

4.5.2. Results

(1) Response Priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.1 %) were excluded.

Mean RTs for correct responses and error rates for each combination of the factors prime congruency and prime type for experts and novices are given in Table 8.

An ANOVA on RTs for correct responses with the factors prime type (novel primes and target primes) and response congruency (incongruent and congruent) revealed a significant interaction between prime type and response congruency, $F(1, 16) = 5.3$, $p < .05$, $\eta_p^2 = .25$. Neither the main effect of prime type nor the main effect of response congruency were significant, *p*'s > .68. Single comparisons revealed that target primes elicited a significant congruency effect $t(16) = 2.1$, $p < .05$, whereas the congruency effect for novel primes was reversed and marginally significant, $t(16) = -1.8$, $p < .10$. Participants responded faster to congruent (415 ms) rather than incongruent (407 ms) target primes. For novel primes, participants tended to respond faster for incongruent (408 ms) rather than congruent (415 ms) trials.

Table 8

Mean RTs (in Milliseconds) and Percentages of Errors for response priming (for target and novel primes) and perceptual priming (for location and form priming) concerning incongruent and congruent primes and the resulting congruency effects (in ms) in Experiment 8

	Response priming		Perceptual priming	
	Target primes	Novel primes	Location	Form
RTs				
Incongruent prime	415 (18.4)	408 (20.4)	414 (18.8)	409 (20.0)
Congruent prime	407 (19.6)	415 (18.5)	405 (20.3)	409 (19.1)
Congruency effect	8*	-7	7*	0
Error rates				
Incongruent prime	7.8 (1.1)	6.2 (1.1)	7.5 (1.0)	6.6 (1.1)
Congruent prime	5.1 (0.9)	8.1 (1.2)	5.8 (0.9)	6.7 (0.8)
Congruency effect	2.7*	-1.9	1.7*	-0.1

Note. Corresponding standard errors are shown in parantheses. Discrepancies in the computed congruency effect result from rounding errors. RTs = reaction times.

* $p < .05$.

The same ANOVA on error rates yielded a similar pattern of results. Again, the interaction between prime type and response congruency was significant, $F(1, 16) = 10.3$, $p < .01$, $\eta_p^2 = .39$, but neither the main effect of prime type nor the main effect of response congruency were significant, *p*'s > .20. Single comparisons showed that again target primes, with 5.1 % errors in congruent trials compared to 7.8 % errors in incongruent trials, yielded a congruency effect (t(16) = 2.9, p < .05)), whereas novel primes elicited a significant reversed congruency effect (t(16) = -2.9, p < .01)) with 8.1 % errors in congruent trials compared to 6.2% errors in incongruent trials.

(2) Perceptual priming

For the analysis of perceptual priming effects, target primes and novel primes were analyzed together. RTs for correct responses and error rates for the combination of the factors location congruency and form congruency are given in Table 8.

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.4 %) were excluded. Averaged data across all participants are presented in Figure 18.

An ANOVA on RTs for correct responses with the factors location congruency (incongruent and congruent) and form congruency (incongruent and congruent) revealed a significant main effect for location congruency, $F(1, 16) = 7.8$, $p < .05$, $\eta_p^2 = .33$. Participants responded faster when the location of the attacker was the same in prime and target diagram (405 ms) rather than when the location of the attacker differed between prime and target diagram (414 ms). Neither the main effect of form congruency nor the interaction location congruency x form congruency were significant, p's > .57.

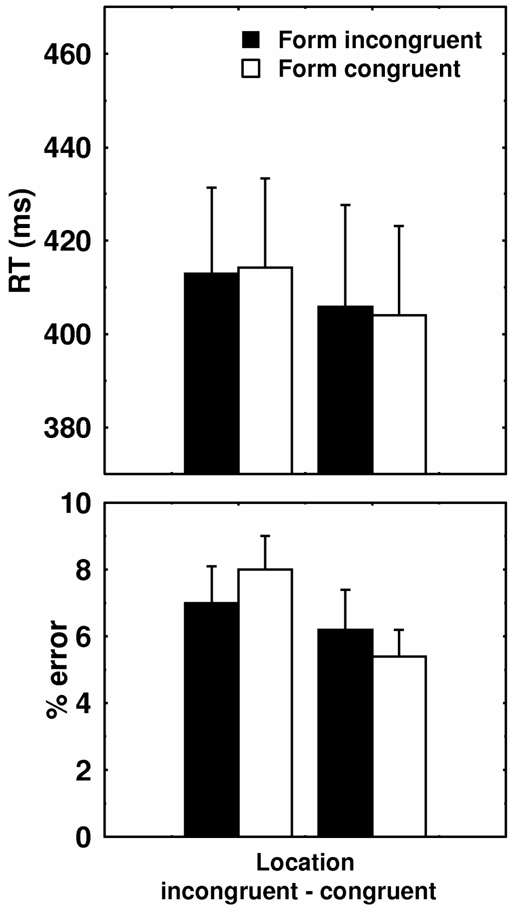

Figure 18. Novices mean RTs (upper panel) and error rates (lower panel) for all primes depending on perceptual congruency (location and form) in Experiment 8. Lines represent standard errors.

The same ANOVA on error rates (see Figure 18) mirrored these results. The main effect of location congruency was significant, $F(1, 16) = 11.1$, $p < .01$, $\eta_p^2 = .40$, indicating that participants made more errors when the attacker's location in prime and target diagram was different (7.5 %) vs. same (5.8 %). The other factor and the interaction revealed no significant effects, *ps* > .23.

(3) Prime visibility

Participants' discrimination performance for check vs. non-check primes was *d´* = .25 and was significantly different from zero, $p < .05$. To test whether the priming effect is related to prime visibility, a priming index for the RT congruency effect was computed for each participant. A subsequently performed linear regression analysis revealed a significant correlation between *d'* and the priming index for location priming, $r = .662$, $F(1, 16) = 11.7$, $p < .01$, whereas the intercept of the regression was not larger than zero (intercept = 2.43, $t(15) = .59$, $p = .13$), indicating that perceptual location priming effects depended on prime visibility.

4.5.3. Discussion

Experiment 8 shows that location priming is stronger than response priming even when form and response congruency are connected. In Experiment 8, novices responded faster and less error prone for response congruent than incongruent target primes. For novel primes, there was a reversed response congruency effect which was marginally significant in RTs and significant in error rates. As the analysis for perceptual priming effects revealed, this reserved response congruency effect for novel primes derives from location priming which for novel primes opposed response as well as form congruence. Form congruence on the other hand, did not influence responding for novel primes, although it was party related to response congruency. Thus, location congruency was decisive for the response to the diagrams, irrespective of response or form congruence.

Therefore, the pattern of results in Experiment 8 is in line with observations made in the previous Experiments 4-7 showing that the feature location is preferably processed also when it is presented for a rather short time and masked.

In Experiment 8, the prime diagrams could be detected above chance and the visibility rating was higher than in all other previous experiments where the prime duration was also just 20 ms (Experiment 1-3 and 5-7). In Experiment 1-7 for the discrimination task, participants had to make the same decision with the prime diagrams as with the target diagrams in the main experiment (i.e. check detection task in Experiment 1, 3-7 or XOR task in Experiment 2). So, it was necessary, to integrate the features location and form in order to make the correct decision upon the prime diagram. Contrary to Experiment 1-7, now in Experiment 8, detecting either only the location or only the form of the attacker in the prime diagram was sufficient for the right response, leading to a discrimination performance above zero. This pattern of results indicates that also in masked priming experiments it is more difficult to identify conjunction stimuli than single features, what is in line with Treisman's feature-integration theory (Treisman and Gelade, 1980; Treisman, 1996). However, the current study was not addressed to elaborate on this question to whose answers further research is necessary.

Finally, Experiment 8 provides evidence for response priming for novices. However, the observed response priming effect for target primes is confounded with perceptual priming, because in contrast to incongruent trials congruent pairs of target prime and target were either location as well as form congruent or the attacker was located on a nearby square. Furthermore, prime presentation was not entirely subliminal. So, until now it is unclear whether it is possible to elicit response priming in novices within the present paradigm. Therefore, Experiment 9 was designed to find out whether it is possible to find response priming in novices with the stimulus material (3x3 chessboards), task (check detection task), and design (subliminal presentation) used in the previous experiments.

4.6. Experiment 9: Enabling subliminal response priming for novices

Using different pieces located at different squares on a partial chessboard Experiment 4-8 showed that single-feature perceptual priming outperformed response priming. With somewhat supraliminal stimuli (Experiment 4) I found reliable response priming, yet the perceptual effects of location and form were much stronger than the response activating effect (2-3 times in size, respectively). However with subliminal stimuli (Experiment 5-7) and perceptual priming at the same time, response priming failed to reach significance.

Therefore, the purpose of Experiment 9 was to pave the way for response priming by eliminating the confounding influences of perceptual location and form priming while applying again a subliminal check detection task. To do so, four different 3x3 chess diagrams were presented as primes and as targets (see Figure 19). Four different pieces were used as attacker (making it possible to rule out form priming) that was always diagrammed on the same square (eliminating location priming). A black king was always presented on the top middle square and one of four different white pieces was presented on the bottom middle square. Queen (panel A) and rook (panel C) checked to the king whereas knight (panel B) and bishop (panel D) did not. Thus, besides identical prime-target repetitions (A-A, B-B, C-C, D-D), prime and target diagrams are response congruent when both prime and target diagram are checking (A-C, C-A) or nonchecking situations (B-D, D-B), otherwise they are response incongruent (A-B, B-A, A-D, D-A, B-C, C-B, C-D, D-C).

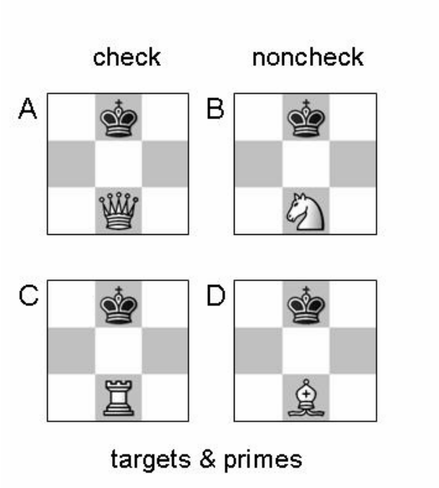

Figure 19 Stimulus set used in Experiment 9: The 3x 3 grids either diagrammed a checking configuration (panels A and C) or a nonchecking configuration (panels B and D).

4.6.1. Methods

(1) Participants

16 chess novices (aged 20-37, mean 24.9) participated each in an individual session of approximately 55 min. All participants declared having normal or corrected-to-normal vision and were not familiar with the purpose of the experiment.

(2) Apparatus and Stimuli

Apparatus and Stimuli were identical to Experiment 8 except for the following changes. Four different 3x3 chessboards were used both as primes and targets. A black king was always located in the upper middle square and a white attacker (either queen, rook, knight, or bishop) was always located on the bottom middle square.

(3) Design and Procedure

Design and Procedure were identical to Experiment 3 except for the following changes: The experiment consisted of 10 blocks in which each combination of prime (4) x target (4) was presented four times in random order (640 trials altogether). The experiment finished with a detection task with 128 identical trials.

4.6.2. Results

(1) Response priming

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (1.9 %) were excluded. Mean RTs for correct responses and error rates of the factor response congruency are persented in Table 9.

Table 9

Mean RTs (in Milliseconds) and Percentages of Errors for response priming, for incongruent and congruent primes (identical prime-target repetitions as well as non-identical prime-target repetitions) and the resulting congruency effects (in ms) in Experiment 9

	Response priming	
	identical repetitions	non-identical repetitions
RTs		
Incongruent prime	438 (9.4)	
Congruent prime	427 (12.5)	430 (11.2)
Congruency effect	10*	7*
Error rates		
Incongruent prime	6.5 (0.9)	
Congruent prime	5.2 (1.0)	4.7 (1.1)
Congruency effect	1.3	1.9*

Note. Corresponding standard errors are shown in parantheses. Discrepancies in the computed congruency effect result from rounding errors. RTs = reaction times.

* $p < .05$.

An one way ANOVA on RTs for correct responses with the factor response congruency (incongruent – congruent nonidentical prime-target pairs - congruent identical prime-target repetitions) revealed a significant main effect for response congruency, $F(1, 15) = 3.8$, $p < .05$, $\eta_p^2 = .20$.

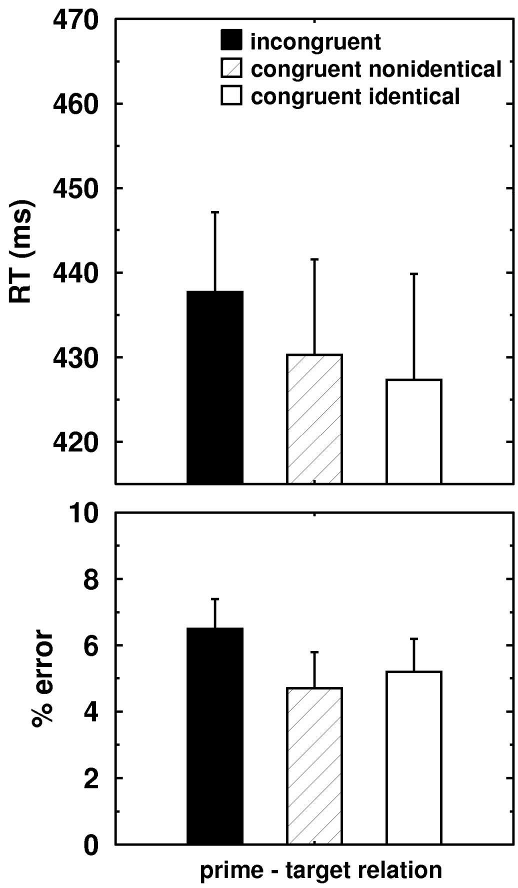

Figure 20. Novices mean RTs (upper panel) and error rates (lower panel) depending on the prime-target relation (incongruent – congruent nonidentical – congruent identical) in Experiment 5. Lines represent standard errors.

Single comparisons revealed that identical prime-target repetitions $t(1, 15) = 2.2$, $p < .05$, and non-identical prime-target repetitions $t(1, 15) = 2.3$, $p < .05$, elicited significant response congruency effects (see Figure 20). Participants responded faster to congruent identical prime-target repetitions (427 ms) rather than to incongruent prime-target pairs (438 ms) as well as faster to congruent non-identical prime-target pairs (430 ms) rather than to incongruent prime-target pairs (438 ms). There was no significant difference between congruent identical prime-target repetitions and congruent non-identical prime-target pairs, $t(1, 15) = -.8$, $p >$ .42.

The same ANOVA on error rates also revealed a significant main effect for response congruency, $F(1, 15) = 3.6$, $p < .05$, $\eta_p^2 = .19$. Single comparisons showed that only non-identical prime-target repetitions $t(1, 15) = 2.5$, $p < .05$, with 4.7 % errors in congruent compared to 6.5 % in incongruent trials, yielded a significant response congruency effect.

(2) Prime visibility

Participants' discrimination performance for check vs. non-check primes was *d´* = .-041 and did not deviate significantly from zero, $p > .42$.

To test whether the priming effect is related to prime visibility, a priming index for the RT congruency effect was computed for each participant and identical and non-identical congruency effects. A subsequently performed linear regression analysis revealed no significant correlation between *d'* and the priming index neither for identical prime-target repetitions $r = .306$, $F(1, 15) = 1.45$, $p > .24$, nor for non-identical prime-target pairs $r = .156$, $F(1, 15) = .35$, $p > .56$. The intercept of the regression was larger than zero for identical prime-target repetitions (intercept = 3.15, $t(15) = 2.64$, $p < .05$) as well as for non-identical prime-target pairs (intercept = 2.07, $t(15) = 2.42$, $p < .05$, indicating that significant response priming effects are associated with *d'*-values of zero.

4.6.3. Discussion

After eliminating the disturbing bottom up-influences of perceptual location and perceptual form priming, I found subliminal response priming for novices even for nonidentical prime-target repetitions with the subliminal check detection task. The size of the RT priming effect from identical prime-target repetitions (11 ms) and non-identical prime-target pairs (8 ms) does not differ significantly from each other. Thus, in Experiment 5, additional perceptual form priming had a minor role compared to response priming.

In contrast to Experiment 4 and 8, the response priming effect observed in Experiment 9 does not come along with an enhanced prime visibility. In Experiment 9, the prime discrimination rate did not deviate significantly from zero; nonetheless different diagrams elicited response priming. Therefore, response priming for masked chess diagrams presented to novices does not depend on prime visibility. Moreover, comparing the different designs and results of participants' discrimination performance in Experiment 8 and 9, reveals that contrary to varying locations, the feature form alone can be changed indeed subliminally. Thus, the feature location does not only have stronger impact on priming, it is also easier to detect than the feature form.

Taken together, the pattern of results in Experiment 9 shows that the stimulus material (3x3 chessboards), task (check detection task), and design (subliminal presentation) used in the previous experiments, is appropriate to elicit response priming even in novices, at least as long as perceptual congruence of location (was always the same for prime and target diagram in Experiment 9) or form (was always different between prime and target diagram in Experiment 9) does not contradict the response congruent response.

5. General discussion

Expertise in a certain stimulus domain enhances perceptual capabilities. In Experiment 1-3, I investigated whether expertise improves perceptual processing to an extent that allows complex visual stimuli to bias behaviour unconsciously. In Experiment 1, expert chess players judged whether a target chess configuration entailed a checking configuration or a nonchecking configuration. As stimuli 3x3 minimized chessboards were are used, where a black king was always located on the upper left corner and a white attacker (knight or rook) was either giving check or no check to the king. These displays were preceded by masked prime configurations that either represented also a checking or a nonchecking configuration. Chess experts, but not novice chess players, revealed a subliminal response priming effect, that is, faster responding when prime and target displays were congruent (both checking or both nonchecking) rather than incongruent (one display checking and the other display nonchecking). Priming generalized to novel displays (where knight and rook were located on new squares) that were not used as targets, ruling out simple S-R repetition priming effects. Thus, chess experts were able to judge unconsciously presented chess configurations as checking or nonchecking, whereas novices were unable to process the chess configurations unconsciously. Experiment 2 demonstrated that experts' priming does not occur for simpler chess configurations which afforded an unfamiliar classification. 3x3 displays, where the king was removed and only a white knight or rook was presented, did not induce a response priming effect in experts, who followed the same stimulus-response mapping as in Experiment 1, but were given an XOR instruction. I conclude that long-term practice prompts the acquisition of visual memories of chess configurations with integrated form-location conjunctions. These perceptual chunks enable complex visual processing outside of conscious awareness. The purpose of Experiment 3 was to find out whether chess experts are able to process even more complex stimuli unconsciously and in parallel. As stimuli sixteen different 3x3 minimized chessboards were presented as targets where besides the location of the white attacker, the location of the black king also varied. Response priming for target primes as well as novel primes was largely eradicated, indicating that chess experts are not able to process perceptual features in parallel or alternatively, that chess experts are not able to form specific expectations which are obviously necessary to elicit priming if many chess displays are applied.

The aim of Experiment 4-9 was to elaborate on unconscious processing of the single features location and form within a response priming paradigm. Experiment 4 and 5 directly contrasted semantically based response priming via learned S-R links and perceptual priming (with the features location and form). For this reason, novices were again provided with a subliminal check detection task. In Experiment 4, the same stimuli, design and task were used as in Experiment 1, but prime induced activation was boosted by increasing prime duration from 20 to 29 ms. As a result, response priming as well as perceptual location priming and perceptual form priming were observable. However, perceptual priming was much more prevailing than response priming (the size of the priming effect was at least 2-3 times larger). In Experiment 5, prime duration was set back to 20 ms, but the amount of trials was massively increased by novices practising the S-R mapping extensively. Nevertheless, under this condition response priming disappeared. Perceptual priming (for the features location as well for form) was reduced in size but nonetheless significant. Additionally, in Experiment 4 and 5, perceptual form priming was only present on expected target locations (demonstrating a top down modulation of this low-level priming by perceptual features). Experiment 6 and 7 were designed to investigate how robust perceptual location priming for novices is. In Experiment 6, the attacker in the target diagram was always a rook presented on four different squares. In the prime diagram not only a rook but also a knight (a different and unexpected form) elicited perceptual location priming effects. Experiment 7 showed that perceptual location priming even transferred to a different and unexpected colour. In the target diagram always a black rook was presented. In the prime diagram a white rook as well as a white knight elicited perceptual priming. Moreover, in Experiment 8, location and form priming, which was additionally related to response priming, were directly compared. The diagrams used as targets were constructed in a way that the features location and form of the attacker were redundant for the required response. For novel prime diagrams, the form of the attacker was response congruent, whereas the location was response incongruent. Reversed response priming for novel primes as well as location priming underlined the privileged processing of the feature location. Finally, Experiment 9 demonstrated that with the subliminal check detection task it is possible to induce response priming when the confounding influences of location and form are absent. As prime and target stimuli four different diagrams were used. One of four attackers (queen, rook, knight, or bishop) was always located on the same square, in vertical opposition to the king. Target responses were facilitated when the relation to the king was the same in prime and target diagram, e.g. a target diagram where a queen was giving check to the king was faster responded to when in the same trial a rook (that was also giving check to the king) was presented in the prime diagram compared to a knight or bishop (that was giving no check to the king) in the prime diagram

In the following, firstly, I will discuss possible underlying mechanisms of different subliminal perception in experts and novices. Secondly, I will focus on subliminal perceptual priming in novices, especially on the impact of the features location and form. And finally, I will discuss a framework, the action trigger account (e.g. Kunde et al., 2003) that integrates the different results of the present work.

5.1. Subliminal perception in experts and novices

In Experiment 1, chess experts could rely on perceptual chunks where the critical features of the attacker location and form are already bound together. In contrast, novices had first to consider the perceptual features (form as well as the location of the attacker) separately, before responding to the target diagram was possible. This demonstrates that subliminal perception qualitatively differs in experts and novices. In the following, I discuss some recent studies that are related to this finding. Recently, Kiefer and Martens (2010) found that compared to a preliminary semantic classification task, an induced perceptual task can attenuate consecutive semantic response priming. Kiefer and Martens (2010) used a lexical decision task to measure the impact of the preliminary task on semantically based response priming. Whereas concerning the recognition of words all participants usually can be considered as experts, it is conceivable that in the present experiments in contrast to experts, for novices, an initial perceptual classification (of the location as well as the form of the attacker) was always necessary in order to be able to decide whether the king is in check or not. Thus, considering the results of Kiefer and Martens (2010) study, it is possible that in Experiment 1 the initial perceptual classification, that was necessary for novices in order to follow the task, diminished response priming.

Moreover, the comparison of experts and novices in Experiment 1 has some drawbacks as it is conceivable that pre-experimentally existing differences between the two groups, i.e. population biases, contaminated the results. For example, there were more male participants in the expert group than in novice group. Or it is possible that the experts were more technically interested and were also more familiar with computer usage and with playing action video games, than the novices. It has been shown that playing action video games leads to a wide range of enhancements in perceptual processing inclusive a higher temporal resolution and a better visual discrimination (Green & Bavelier, 2003; Green et al., 2010). Therefore, it is (not likely, but) possible that other characteristics than former chess experience were responsible for the observed priming differences between experts and novices in Experiment 1. Moreover, in order to answer the question whether chess experts rely on perceptual chunks or whether they were able to unconsciously resolve a XOR-task, in Experiment 2 it was necessary not only to change the instruction but also to remove the king in the diagrams, because otherwise chess experts would have probably realized the difference between the two diagrams with a check situation and the two diagrams with a no check situation. Thus, it cannot be definitely ruled out that in Experiment 2, the changed stimuli (compared to Experiment 1) somehow hindered response priming for chess experts.

In order to rule out these alternative explanations and to generalize the findings from Experiment 1 and 2 to another domain of expertise, we conducted a subliminal priming experiment using combinations of two letters as stimuli (Reuss et al., 2009). Two groups of participants were provided with the same stimuli used as primes and targets (the letter combinations *so*, *se*, *os*, and *es*). Both groups had the same response mapping, but got different instructions. One group had to categorize the target as being a word or a non-word (lexical task), whereas the other group had to respond to the combination of the location and identity of the vowel (XOR task). As a result, there was a significant interaction of response congruency and task, indicating that the task instructions had a fundamental influence on response priming. In the lexical task but not in the XOR task, a response priming effect was observed. A second analysis focusing on perceptual priming (congruence of the location and identity of the vowel between prime and target) showed the reversed pattern of results. In the XOR task, performance was best when both features were the same, and worst when both features were different. In contrast, in the lexical task, performance was best when both features were the same, but also when both features were different. Thus, when the stimulus as a whole had to be categorized in a domain and with a task for which participants are highly trained (i.e. reading) they can access perceptual chunks. In these chunks different features are already integrated so that they are processed as if they were a single stimulus, even when they are presented subliminally. As a consequence response priming according to the mapping that had been made for the whole stimulus (i.e. word) emerged. However, when the same stimuli were presented, but attention was focused on single features through an (XOR-) task, then every single stimulus (i.e. letter) – also when presented subliminally - was processed independently. Then, as a consequence, the single features (i.e. location and identity/form) elicited perceptual priming.

Meanwhile, also in other domains of expertise it has been demonstrated that in contrast to novices, experts are able to process relatively complex expertise-related stimuli (in a holistic manner) even when they are presented unconsciously. So far, (stronger) subliminal response priming has been found for the own face (Pannese & Hirsch, 2010), the own name (Pfister, Pohl, Kiesel, & Kunde, 2011), for skilled athletes when pictures of jumps were presented in the correct temporal order (Güldenpennig, Koester, Kunde, Weigelt, & Schack, in press), or for words in the first language as primes presented before words in the second language as targets (Schoonbaert, Duyck, Brysbaert, & Hartsuiker, 2009).

The study of Reuss and colleagues (2009) shows that even with the same stimulus material and the same amount of expertise with the appearance of the stimuli, priming depends on the demanded task. Thus, (perceptual) expertise not only comes from a higher familiarity with the (visual) objects of expertise through to extensive exposure, but also from acquired knowledge structures about the relations of and conducted mental operations with the objects of expertise. This is especially true for artificial and somewhat abstract objects. In contrast to tools for example, the form of chess pieces tells nothing about their functions in the game. Of course, it is more or less obvious that some pieces personate historical roles like king, queen or bishop. However, their movement patterns are nevertheless defined arbitrarily. One open question from the present experiments is how much the factors mere visual familiarity on the one hand and knowledge about the relations of the objects on the other hand contributed differently to the observed response priming effects for experts. In all nine experiments stimuli were depictions of chess pieces on a partial diagram. It can be assumed that all experts (Experiment 1-3) are very familiar with this kind of depiction either through playing chess in the internet, using computer programs for gaming analysis or just through the illustrations in chess books. For the most of our novices (they were also asked which kind of experience, i.e. computer chess, casual games, chess books, etc. they had with chess) the form of presenting chess pieces in depicted diagrams was new. Nonetheless, in Experiment 9 where the detrimental influences of perceptual location and form priming were eliminated, novices elicited response priming effects. Moreover, the observed form priming effect for novices throughout Experiment 4-5 somehow indicates that the chess pieces were even unconsciously discriminable for them. Thus, mere visual familiarity with the stimulus material seems to have had a minor influence in the present experiments. The amount of previous practise in the game of chess (operating mentally with the chess pieces) appears to be much more decisive for the ability to process (partial) chessboards unconsciously.

The question of the different influences of familiarity with mere perceptual appearance of the objects of expertise and experience with the relations of the objects i.e. their functions was indirectly addressed in another series of experiments using fMRI and eye tracking additionally to behavioural measurements (Bilalić, et al., 2011). The stimuli used as targets were almost the same four partial chessboards than in Experiment 1, 4, or 5. Only the colour of king and attacker was interchanged. A black knight or a rook gave check to a white king or not. Additionally there were four diagrams were instead of the king a circle and instead of knight or rook a square or diamond was presented, respectively. Participants were either expert chess players (mean Elo 2130 points) or novices who played chess occasionally but had never participated in tournaments. There were four different tasks: an identity task (is there a knight or a rook presented?), a check detection task (is the king in check or not?) a first control task (is there a diamond or a square presented?), and a second control task (is there a diamond on a grey location or a square on a white location presented or is there a square on a grey and a diamond on a white location presented? (XOR-task, see Experiment 2 for the application of the same task). Chess experts were faster, needed fewer fixations, and fixated more often at the centre of the chessboard and beside the pieces than novices when chess stimuli were presented. However, concerning RTs, in the identity task, there were larger differences between experts and novices in the first quarter compared to the other three quarters of the experiment, because novices caught up over time while experts' performance seemed to reach soon a ceiling effect. No differences between experts and novices were found in the two control conditions that afforded similar tasks but with different stimuli, whereas the second control condition (the XOR-task) was the most difficult one for both groups of participants. Neuroimaging data revealed "a network of brain areas responsible for the recognition of chess objects and their functions" (Bilalić et al., 2011, p. 5). This network included the bilateral areas around the parietal-occipito-temporal junction (OTJ, and POTJ), spreading to the posterior middle temporal gyrus (pMTG), as well as the bilateral supramarginal gyrus (SMG). Contrary to novices, compared to the control task, experts showed a higher activation in the right temporo-lateral areas in the check but not in the identity task. However, when compared directly, concerning the activation in both temporal and parietal lateral areas no differences could be found between the check and the identity task, possibly indicating that the recognition of an object is closely related to the recognition of its functions. Thus, besides the main finding that "skilled object recognition does not only involve a more efficient version of the processes found in normal recognition" (Bilalić et al., 2011, p. 1), but rather "may involve qualitatively different cognitive processes which are accommodated in the human brain through engagement of additional homologous brain areas" (Bilalić et al., 2011, p. 8), the results of the study indicate that compared to the role of experience with the relations of the objects i.e. their functions, the impact of mere perceptual familiarity is of minor influence. Moreover, in the course of the experiment, the differences between experts and novices in the identity task were diminishing over time whereas in the check task this was not the case. Thus, learning to respond to the mere perceptual appearance of objects (of expertise) apparently occurs faster than learning to respond to the functional relationships of objects.

5.2. Subliminal perceptual priming

In research about the limits and abilities of the unconscious mind, "it is debated since long whether the preattentively activated representations are either restricted to elementary perceptual features like location, colour, size, shape, pitch, etc. or whether these preattentive representation comprise the conceptual meaning of the registered stimuli" (Pohl et al., 2010, p. 268). In the framework of the present study, response priming was taken as evidence for unconscious stimulus processing according to the conceptual meaning (i.e. integrated features) whereas perceptual priming was taken as evidence for unconscious stimulus processing according to elementary perceptual features (i.e. single features). In contrast to the majority of subliminal response priming studies in which well-known stimuli like words, digits or easy geometrical forms were used, for which everybody can be considered to be an expert, I used stimuli from a special domain (i.e. chess diagrams) for which most people are inexperienced (i.e. novices). As a result, I found clear evidence for perceptual priming in novices according to the single features location and form that also eliminated response priming when contrasted directly. Thus, from the present results, it seems to be that unconscious stimulus processing according to unfamiliar stimuli leads to perceptual processing of single features, whereas it looks like that an enormous amount of practise (i.e. expertise) is a necessary precondition for holistic processing of the conceptual meaning of the stimuli.

Over Experiment 1, 4, 5, 6, and 7, were response priming was contrasted with perceptual priming, for novices I found only limited evidence for response priming which even reversed when response activation was directly opposed with overlap of perceptual features between prime and target within a trial. However, a meta-analytic examination of masked priming (Van den Bussche, et al., 2009) showed that although congruency effects are diminished when the target set contains only few different stimuli and when novel primes are used, nevertheless congruency effects for semantic categorizations as well as for lexical decisions were significant. In the present work, in all experiments with novices a small target set was used containing only four different target displays. Moreover, at least half of the primes were novel primes (in Experiment 7 all primes were novel primes). Thus, it is possible that in some of the experiments of the present work, especially for novel primes, response priming only had a small effect which was too weak to become significant. Therefore, in a metaanalytic manner, novices' data of the five experiments that come into consideration (Experiment 1, 4, 5, 6, and 7) were submitted together into an ANOVA. The ANOVA on RTs for correct responses with the factors prime type (target primes and novel primes) and response congruency (congruent and incongruent) revealed a marginally significant main effect for the factor response congruency, $F(1, 93) = 2.9$, $p < .10$, $\eta_p^2 = .03$. Neither the interaction prime type x response congruency nor the factor prime type, were significant, *ps* > .49. The same ANOVA on error rates revealed no significant effects *p*s > .29. When compared directly, planned t-tests showed that if anything then only target primes ($t(93) = 1.6$, $p = .12$), but not novel primes ($t(93) < 1$), contributed to the formation of the marginally significant response congruency effect. Numerically the response priming effect of target primes averages just about 2 ms. However, when the identical prime-target repetitions in Experiment 1, 4, and 5 and location repetitions in Experiment 6 and 7 are removed, again a reversed response congruency effect ($F(1, 93) = 9.1$, $p < .01$, $\eta_p^2 = .09$) emerges. The marginally significant interaction prime type x response congruency ($F(1, 93) = 3.8$, $p < .10$, $\eta_p^2 = .04$) and planned t-tests showed that then only target primes ($t(93) = -3.8$, $p < .001$), but not novel primes ($t(93) < 1$) contributed to the formation of the significant reversed response congruency effect. The same ANOVA on error rates revealed a reversed response priming effect ($F(1, 93) = 5.2$, $p < .05$, $\eta_p^2 = .11$) that did not depend on prime type (F (1, 93) < 1, for the interaction prime type x response congruency). Thus, the metaanalysis of the five relevant experiments of the present study reveal only very weak evidence for response priming that is even connected with location priming. From these results, it is likely that the absence of response priming was not a (statistical) power problem (in finding small effects) rather than that opposed perceptual congruence indeed eradicated response priming. Therefore, for novices perceptual similarity between prime and target is more important than learned S-R links, although it is also possible to elicit response priming in novices as long as perceptual congruence comes along with response congruence (identical prime-target repetitions) or when at least perceptual congruence does not antagonize response congruence (Experiment 9).

Concerning the perceptual influence of the features location and form, when compared with each other (e.g. Experiment 8), location priming was stronger than form priming, underlining the predominant role of the feature location (cf. Treisman & Gelade, 1980), even for unconscious information processing. On the one hand, it seems that location priming presupposes only the detection of the subliminal stimulus, whereas form priming demands somehow the identification of the stimulus which in turn comprises its previous detection. On the other hand, however, form priming did not necessarily demand the exact detection of the stimulus location. This notion is corroborated by Experiment 5, showing location and form priming independently from each other but no response priming which would only occur when both features had been integrated. Moreover, in contrast to response priming, form priming can probably arise even when the unconscious stimulus identification is incomplete but sufficient to be at least partially similar to the target. However, more research is necessary to answer this question.

5.3. Integration the results – the action trigger account

So far, from a more fundamental point of view, it is yet not clear why for novices the congruence of single perceptual features was more important than the congruence of learnt responses to the arrangement of these features, whereas experts showed the reversed pattern of results. In the discussions of Experiment 1 and 3, the action trigger account (see programmed S-R links on p. 21 in this work) already proved to be suitable to explain the results. However, with a slight upgrading, the action trigger account can also help to understand the results of the other experiments in the present study.

In order to explain contradictory results concerning the effectiveness of novel primes in subliminal priming experiments (e.g. on the one hand, Naccache & Dehaene, 2001; Greenwald, et al., 2003; Reynvoet, et al., 2001 and on the other hand, Abrams, 2008b; Abrams & Greenwald, 2000; Damian, 2001), Kunde and colleagues (2003; see also Kiesel et al., 2007b; Kiesel et al., 2006) proposed a new hypothesis which focuses on the role of task preparation in masked priming experiments. The basic ideas are that stimulus expectations serve for action control and that anticipating stimuli determines their processing. Of course, this idea is not new. Yet, it has an over 100 year tradition in psychology (Ach, 1905; Bargh, 1989; Exner, 1879; Hoffmann, 1993; Hommel, 2000; Neumann, 1990). Like the concept of direct parameter specification (Ansorge & Neumann, 2005; Neumann, 1990; Neumann & Klotz, 1994; Klotz & Neumann, 1999), the action trigger account adopts these ideas to the field of unconscious cognition. The aims of both theories are to predict and to explain under which circumstances unseen stimuli induce motor activation. In the concept of direct parameter specification participants' intentions are crucial. It is assumed that "participants search for information in order to specify free parameters within the currently active intention" (Ansorge & Neumann, 2005; p. 764). In this regard, the action trigger account can be seen as a model to elaborate on how such a direct specification of parameters might work and under which circumstances it takes place.

The action trigger account assumes a two-process model of conscious stimuli preparation and unconscious prime processing. First, when someone wants to act goal-oriented according to stimuli in the environment or also when participants are executing a reaction time experiment, it is necessary to categorize deliberately possible upcoming stimuli in appropriate and non-appropriate release conditions for the intended response (i.e. action triggers are formed). Second, when the stimuli are occurring, then a comparison with the release conditions takes place. In a reaction time experiment, this happens online in each trial. When stimuli and release conditions match, then the prepared action is triggered automatically. This step can also run unconsciously and therefore congruency effects arise, indicating that the prime is processed. However, primes that do not match the release conditions do not elicit congruency effects.

The basic idea behind the action trigger account is that expecting and preparing for certain stimuli enables faster responding. But of course preparation itself is effortful. As a consequence action triggers should be built always as wide as necessary but as narrow as possible. Task instructions and experienced task requirements determine which stimuli are expected and therefore which stimuli are categorized as adequate or inadequate release conditions for the response alternatives. Insights about the concrete form that action triggers can take, comes from a study where pictures were used as primes and targets (Pohl et al., 2010). In the first experiment of this study, only four different pictures of animals were presented as targets and participants had to classify them as being small or large. As a result, priming was restricted to the very same prime pictures as the target pictures. Novel prime pictures that depicted the same animals as the target pictures but in a slightly different illustration and with a reversed left-right orientation were ineffective. Thus, it seems likely that after seeing that these four different pictures were presented again and again as targets, action triggers were built up on the exact sensory image of the seen target pictures. In a second experiment, participants classified 40 different pictures of animals. It is conceivable that after participants had experienced the pictures of many different animals – small animals such as a mouse, a chicken, a lobster, a sea horse, a fly, a cat, a shrunk, and so on, as well as large animals such as a lion, a zebra, a giraffe, a gorilla, a penguin, a tiger, a pig, and so on, they also recollect the pictures of other familiar animals such as for example a bird, an ant, a bear, or a camel. Therefore, they expected many different animals to occur as stimuli and built up action triggers upon them. Supposedly, all primes picturing animals met the expectations of the participants and action triggers were pre-specified for all familiar animals. Accordingly, the results of the second experiment showed that priming transferred to all prime stimuli picturing animals, but not to prime stimuli picturing objects (Pohl, et al., 2010).

The assumption that action triggers are formed as specific as possible explains the results obtained in Experiment 4-8. Action triggers are specified according to concrete visual release conditions (i.e. sensory or perceptual features). However, when the congruence of single perceptual features (e.g. the location or form of a chess piece) within a trial contradict the direction of the response due to programmed (or learnt) S-R links according to the whole percept of the stimulus (e.g. a partial chess diagram), like it is the case for novices in the present study (Experiments 1, 4-7), then conflicting action triggers are activated, resulting in strong perceptual priming and reduced or absent response priming.

The Greek philosopher Aristotle once stated “The whole is more than the sum of its parts”. Whereas this well-known citation has become valid as one of the main statements of Gestalt Psychology, it seems also to accord for stimuli that are presented unconsciously. However, it depends on familiarity or experience (i.e. expertise) whether the statement is true. Concerning unconscious processing of unfamiliar stimuli - at least according to a not well trained task – it seems necessary to reverse the conclusion: “The sum of its parts is more than the whole”.

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