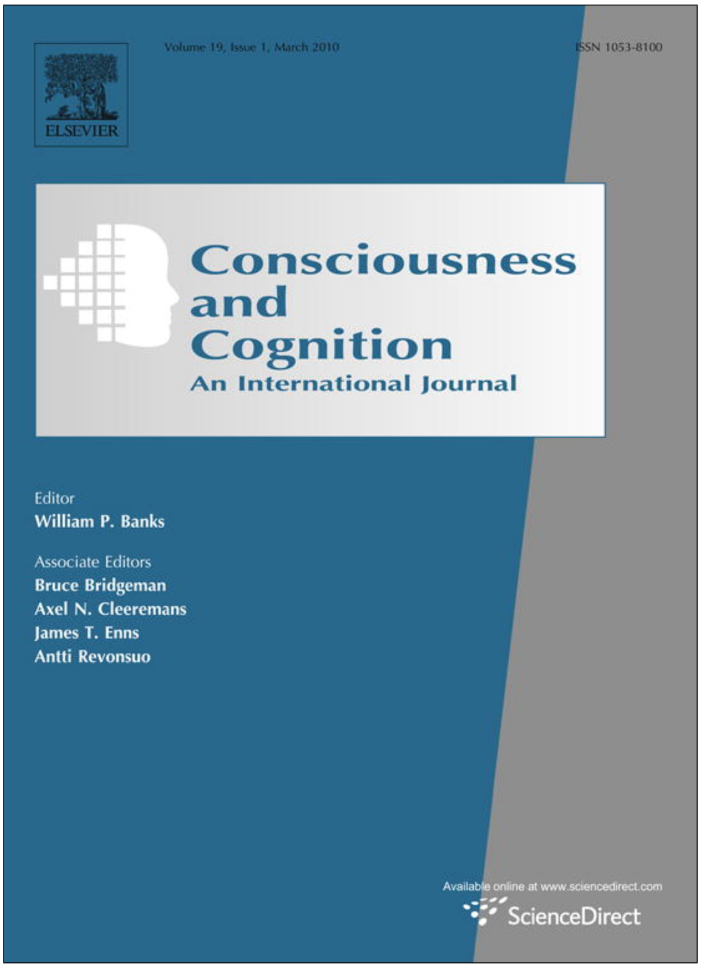
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Short Communication

Masked response priming in expert typists

Alexander Heinemann [a,*], Andrea Kiesel [b], Carsten Pohl [b], Wilfried Kunde [a]

[a] Dortmund University of Technology, Department of Psychology, Emil-Figge-Strasse 50, 44227 Dortmund, Germany
[b] Julius-Maximilians University of Würzburg, Department of Psychology, Röntgenring 11, 97070 Würzburg, Germany

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In masked priming tasks responses are usually faster when prime and target require identical rather than different responses. Previous research has extensively manipulated the nature and number of response-affording stimuli. However, little is known about the constraints of masked priming regarding the nature and number of response alternatives. The present study explored the limits of masked priming in a six-choice reaction time task, where responses from different fingers of both hands were required. We studied participants that were either experts for the type of response (skilled typists) or novices. Masked primes facilitated responding to targets that required the same response, responses with a different finger of the same hand, and with a homologous finger of the other hand. These effects were modulated by expertise. The results show that masked primes facilitate responding especially for experts in the S–R mapping and with increasing similarity of primed and required response.

1. Introduction

It is a well known phenomenon that stimuli can influence behavior even though they are not processed consciously (Dehaene et al., 1998; Klotz & Neumann, 1999; Marcel, 1983). In masked priming experiments participants usually respond to one set of targets with a left key press and to another set of targets with a right key press. For example, typical tasks are classifying a digit as odd or even or as smaller or larger than five (e.g., Dehaene et al., 1998; Kiesel, Kunde, & Hoffmann, 2006; Kunde, Kiesel, & Hoffmann, 2003, 2005; Naccache & Dehaene, 2001). Prior to the target another stimulus, the so-called prime is presented. The prime is presented very briefly and additionally it is masked so that it is impossible to perceive the prime consciously (e.g., Dell'Acqua & Grainger, 1999; Neumann & Klotz, 1994; Vorberg, Mattler, Heinecke, Schmidt, & Schwarzbach, 2003).

Nevertheless, the prime influences responding to the target. If prime and target require the same response they are considered congruent. If prime and target require different responses they are considered incongruent. Usually the response time (RT) after congruent prime–target pairs is faster than after incongruent pairs. This is known as the response congruency effect (e.g., Ansorge & Neumann, 2005; Reynvoet, Gevers, & Caessens, 2005). Under certain conditions, which are not met in the present study, the effect can reverse for reasons explained elsewhere (cf. Eimer & Schlaghecken, 1998; Schlaghecken & Eimer, 1997).

A well established explanation for the response congruency effect is the direct parameter specification (DPS, Klotz & Neumann, 1999; Neumann, 1989, 1990; Neumann & Klotz, 1994). DPS suggests that when participants prepare to execute a task, learned or innate internal control structures are set up. These structures contain open parameters that have to be specified to eventually reach a current action goal. First, it has to be clarified which specific body movements are needed and which are

* Corresponding author. Address: Dortmund University of Technology, Institut für Psychologie, 44227 Dortmund, Germany.
E-mail address: heinemann@fk14.uni-dortmund.de (A. Heinemann).

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not. In case of a two-choice RT task this means that participants prepare for the two possible responses, that is a left or right key press. Second, appropriate "environmental stimulation" has to be specified. In other words, it has to be clarified which stimuli are appropriate release conditions for either of the prepared responses (Neumann, 1989). Importantly, after appropriate release conditions have been specified, any stimulus that matches one of these conditions activates the corresponding action "directly", that is without conscious mediation or reflection. In other word, an appropriate stimulus has the power to directly specify an open action parameter. Therefore primes activate corresponding motor responses in the absence of prime awareness.

Response priming by masked primes has been observed with a variety of stimulus materials, such as arrows (Eimer & Schlaghecken, 1998; Vorberg et al., 2003), squares (Jaskowski, Skalska, & Verleger, 2003), rhombuses (Klotz & Neumann, 1999), numbers (Dehaene et al., 1998), letters (Elsner, Kunde, & Kiesel, 2008; Kiesel, Kunde, & Hoffmann, 2007; Reynvoet, et al., 2005), words (Damian, 2001; Klauer, Musch, & Eder, 2005; Van den Bussche & Reynvoet, 2007), and pictures (Dell'Acqua & Grainger, 1999; Pohl, Kiesel, Kunde, & Hoffmann, in press; Van den Bussche, Notebaert, & Reynvoet, 2009). Several of these studies used considerable numbers of different targets and primes. It is thus undisputed that masked response priming extends to situations where there is a considerable variability on behalf of "environmental stimulation".

A topic that received much less attention than the variability of the environmental stimulation is the variability of response alternatives. Apart from some exceptions (Eimer, Schubö, & Schlaghecken, 2002; Schlaghecken, Bowman, & Eimer, 2006, see below) the fast majority of masked priming studies used two-choice RT tasks. This means, participants only had to decide whether to perform one out of two possible responses (usually whether to respond with a left or a right key press). It seems thus fair to say, that the evidence for masked priming beyond two response alternatives is still confined, and the eventual limits of masked priming regarding the number of response alternatives are unknown. To explore these limits was one purpose of the present study.

For this purpose, we used a task with six response alternatives. Participants were presented one of six capital letters (S, D, F, J, K, and L) and had to press the corresponding key on a standard QWERTZ keyboard. Before the target letter a masked prime was presented. Primes were the same letters as the targets presented in lower-case (s, d, f, j, k, and l).

The motivation to use this particular task is twofold. First, there is considerable evidence that this set of responses is cognitively represented and controlled by means of two motor parameters, namely the hand to be used (left vs. right) and the finger to be used (index, middle, ring). Evidence for this stems from response preparation studies. These studies found that hand and finger parameters can be used, more or less efficiently, to prepare for a to be executed action, although there is some controversy whether preparation concerns anatomical features of the responses or their spatial location (Miller, 1982; Reeve & Proctor, 1984; Ulrich, Leuthold, & Sommer, 1998; Wild-Wall, Sangal, Sommer, & Leuthold, 2003). The question that arises here is whether or not masked response priming effects reflect this parameter-based representation as well. Specifically, does a masked prime facilitate responding only when prime and target share both motor parameters (e.g., both signal a response with the index finger of the right hand) or does it facilitate responses that share only one parameter (either the same hand or the same finger)? Such "parameter-related" response priming would suggest that primes do not only activate the specific response that they require but, to some extent, so to say collaterally, responses that are similar in terms of the motor-control parameters. This collateral priming was not systematically examined in previous masked priming studies that employed more than two response alternatives. Schlaghecken et al. (2006) found that costs of incongruent primes decreased when the number of possible movement directions of a single responding finger was increased from two to four. This study focussed on the global comparison of congruency effects *between* 2 and 4 response alternatives, but did not examine the pattern of congruency effects of different pairs of prime and target responses *within* a set of more than two responses. Another study by Eimer et al. (2002) used four choice responses with hand and feet. This study revealed that priming effects can transfer between hand and foot of the same body side, when the prime signals the body side. Yet, this study was concerned with *negative* congruency effects, likely due to self-inhibition of a primed response, and did thus not directly address the issue of positive priming that we explored here. Thus, the present study extents these previous reports in terms of number of response alternatives and the possible mechanisms that mediate priming with such a large number of response alternatives.

Second, the response set employed here allowed us to study the role of pre-experimental expertise on masked response priming. Obviously pressing keys to the presented letters is an extremely practiced task for skilled typists whereas it is less practiced for those who are unfamiliar with the 10-fingers typing system.

There is already some evidence that target letters tend to automatically activate the finger that is needed to type this letter with skilled typists (Rieger, 2004, 2007). Whether this activation extends to masked primes as well, and whether this effect is bound to high levels of expertise is unknown. Interestingly, the role of practice for masked priming has generally received little attention so far (cf. Kiesel, Kunde, Pohl, Berner, & Hoffmann, 2009; Schlaghecken, Blagrove, & Maylor, 2008 for exceptions). To explore the role of pre-experimental expertise we employed two groups of participants, namely skilled typists and novices of the 10 finger typing system.

The type of stimuli and responses resulted in four different prime–target relations. First, the prime requires a response with the same finger of the same hand as the target. Second, the prime requires a response with a different finger of the same hand. Third, the prime requires a response with the homologous finger of the other hand. And fourth, the prime requires a response with a different finger of the other hand than the target. With this distinction one can expect to find two types of congruency effects. First, if prime and target require responses with fingers of the same hand they are considered hand-congruent. Otherwise, they are considered hand-incongruent. Second, if prime and target require responses with the same finger (either of the same or of the other hand) they are considered finger-congruent. Otherwise, they are considered finger-incongruent.

The crucial question was whether primes activate target responses that correspond to the prime-assigned response regarding the hand-parameter, the finger-parameter, or the combination of both. Different scenarios appear possible. First, target responses might benefit from primed responses that share either the hand-parameter or the finger-parameter, with these benefits being additive. This would suggest that primes activate responses along both parameters, independently of each other. Second, there is some evidence that the hand-parameter can be programmed more efficiently than the finger-parameter (Miller, 1982; Reeve & Proctor, 1984). It might therefore turn out, that target responses profit from primes that are assigned to the same hand but not to a homologous finger. In this case we should see a main effect of hand congruency but no effect of finger congruency. Third, it might be that primes activate only one specific response, that means a specific conjunction of both parameters (e.g., right hand and index finger). In this case we should see an interaction of hand and finger congruency: Responses should be fast when prime and target are congruent regarding hand and finger, with no difference between all remaining conditions. Such an outcome would question the whole idea of parameter-based representation of response, but would instead suggest an exemplar-based representation of the six response alternatives.

On top of that, the priming patterns might differ between experts and novices. We expected that the level of prime-induced response activation would be overall higher for skilled typist who extensively practiced the S–R mapping compared to novices regarding the 10-fingers typing system. Additionally, with higher prime-induced response activation the spread of activation to feature-overlapping responses might increase as well. Consequently, there might be more hints for a priming of target responses from the same hand or a homologous finger with typing-experts compared to typing-novices.

2. Method

2.1. Participants

Twelve skilled typists (mean age: 26.3, $s = 8.0$) who were capable to type fluently with the 10-finger-system and 24 novices (mean age: 27.4, sd = 9.8) who usually used hunt-and-peck typing with two fingers volunteered to participate each in an individual session of approximately 60 min. All reported to have normal or corrected to normal vision and were naïve to the purpose of the experiment.

2.2. Apparatus and Stimuli

An IBM-compatible computer with a 17-in. (43.18-cm) VGA display (vertical retraces 100 Hz; monitor resolution 1024×768 pixels), the software package E-Prime (Schneider, Eschman, & Zuccolotto, 2002) and a QWERTZ computer keyboard were used for stimulus presentation and response sampling. The prime was chosen out of six lower-case letters (s, d, f, j, k, and l). The target was chosen out of six capital letters (S, D, F, J, K, and L). For pre and post-masks three hash signs (###) were used. All stimuli were presented centered on the screen in white on a black background in Courier New 36. The hash signs in the masks were printed in bold (resulting in 7 mm width and 10 mm length on the screen for each hash sign), whereas prime letters and target letters were printed in normal format (resulting in 5–8 mm width and 9 mm length on the screen).

2.3. Procedure

Participants were instructed to place their index, middle, and ring finger of each hand on the S, D, F and J, K, L-keys of a regular computer keyboard (note that these are also the prime and target letters). Participants were to respond to the target letters by pressing the respective key as fast as possible. Each trial started directly with a pre-mask (presented for 70 ms), followed by a prime (20 ms), a post-mask (50 ms), and a target (200 ms). Errors were indicated by the German word for wrong ("Falsch!") presented in red in the lower part of the monitor. Twelve experimental blocks were presented with 60 trials each. Participants were encouraged to take short breaks between the blocks.

Each target letter was presented 10 times per block. In a block each target letter was preceded five times by the same prime letter and once by each of the other five letters.

After the 12 experimental blocks a visibility task was conducted. Participants were fully informed about the presentation of the primes and were now asked to identify whether the prime letter presented in a trial had been the same as the target letter. They were told that the possibility for identical prime–target presentation is exactly 50%. This yes/no-response mode enabled us to compute d' as a measure of prime visibility. The prime categorization task consisted of one block with 120 trials. The trial structure was identical to the experimental blocks.

At the end of the experiment, we measured the typing skills. Participants had to copy type a newspaper text for 5 min. Whereas skilled typists were instructed to use the 10-finger-system, novices were instructed to type as they usually did, because we wanted to check whether they really applied a 2-finger-typing-system. All novices proofed to be 2-finger-system users. Mean number of correct keystrokes were 853 for novices, sd = 239 (minimum = 486, maximum = 1542) and 1501 for typing-experts, sd = 284 (minimum = 858, maximum = 1840).

3. Results

We split the data regarding the factors hand congruency (same vs. different hand), finger congruency (same vs. different finger), and the between-subject factor expertise (skilled typists vs. novices). This allowed us to test all hypotheses at once: Whether there is priming in a six-choice RT task, whether overlap regarding both parameters (hand and finger) exerts response priming and, if so, whether pre-experimental expertise modulates the pattern of response priming. Hand and finger-congruency effects are computed by subtracting the respective mean of the dependent variable (RTs or percentage of errors) in the congruent condition from the mean in the incongruent condition. If RTs and error rates in the incongruent condition are slower than in the congruent condition the priming effect is positive.

3.1. Response times

Trials with RTs deviating more than 2.5 standard deviations from the mean RT of each participant and each experimental condition (2.0%) as well as incorrect trials (4.9%) were excluded from the analysis.

Mean RTs of correct responses were submitted to an analysis of variance (ANOVA) with the within-subject factors finger congruency (same finger vs. different finger) and hand congruency (same hand vs. different hand) and the between-subject factor expertise (skilled typists vs. novices) (see Table 1).

Experts responded 231 ms faster than novices (523 ms vs. 754 ms), $F(1, 34) = 40.30$, MSE = 1.700.000, $p < .001$. When the prime required responding with the same hand as the target, mean RTs were 13 ms faster than when prime and target required responding with different hands, $F(1, 34) = 16.27$, MSE = 5190, $p < .001$. When the prime required responding with the same finger as the target, mean RTs were 11 ms faster than when prime and target required responding with different fingers, $F(1, 34) = 22.92$, MSE = 3931, $p < .001$. The congruency effect for the factor finger was 16 ms in case of hand congruency and it was reduced to 6 ms in the hand-incongruent condition. Yet, the interaction of hand congruency and finger congruency missed significance, $F(1, 34) = 2.06$, MSE = 709, $p = .16$.

Expertise modulated the finger-congruency effect, $F(1, 34) = 7.61$, MSE = 1365, $p < .01$. For skilled typists, there was a finger-congruency effect of 18 ms ($t(11) = 5.38$, $p < .001$), while for novices the finger-congruency effect was reduced to a non-significant 5 ms difference ($t(23) = 1.66$, $p = .11$). The interaction hand $\times$ expertise, $p > .11$, and the three-way interaction finger $\times$ hand $\times$ expertise did not reach significance, $p > .42$.

Overall RT level of skilled typists and novices differed. It is therefore conceivable that we did not observe congruency effects in novices because the prime-induced activation faded in time. To elaborate whether this suspicion holds true, we examined RT distributions. For this purpose we computed percentile values of 5%, 15%, ...95% for each congruency type. Fig. 1 shows the distributions.

Fig. 1A and B display the RT distributions for novices (left side) and skilled typists (right side) for hand-congruent and hand-incongruent conditions (Fig. 1A) and for finger-congruent and finger-incongruent conditions (Fig. 1B). In Fig. 1C the net congruency effects for hand congruency (left side) and finger congruency (right side) are shown for each percentile for novices and skilled typists. Examination of the RT distribution reveals that the RT differences in incongruent and congruent conditions for typists and novices do not depend on the overall RT level (except for percentile 95%). Thus, we can rule out that the overall increased RT level were responsible for the reduced congruency effects in novices.

3.2. Errors

Mean percentage of errors (PE) were submitted to an ANOVA with the within-subject factors hand congruency (same hand vs. different hand), finger congruency (same finger vs. different finger) and the between-subject factor expertise (skilled typists vs. novices) (see Table 2).

Table 1
RTs and (standard errors) for skilled typists and novices split by hand congruency and finger congruency.

	Hand		
	Congruent	Incongruent	Hand congruency
Typists			
Finger			
Congruent	502 (32)	527 (27)	25
Incongruent	527 (31)	537 (30)	10
Finger congruency	25	10	
Novices			
Finger			
Congruent	747 (23)	756 (19)	9
Incongruent	753 (22)	759 (21)	6
Finger congruency	6	3	

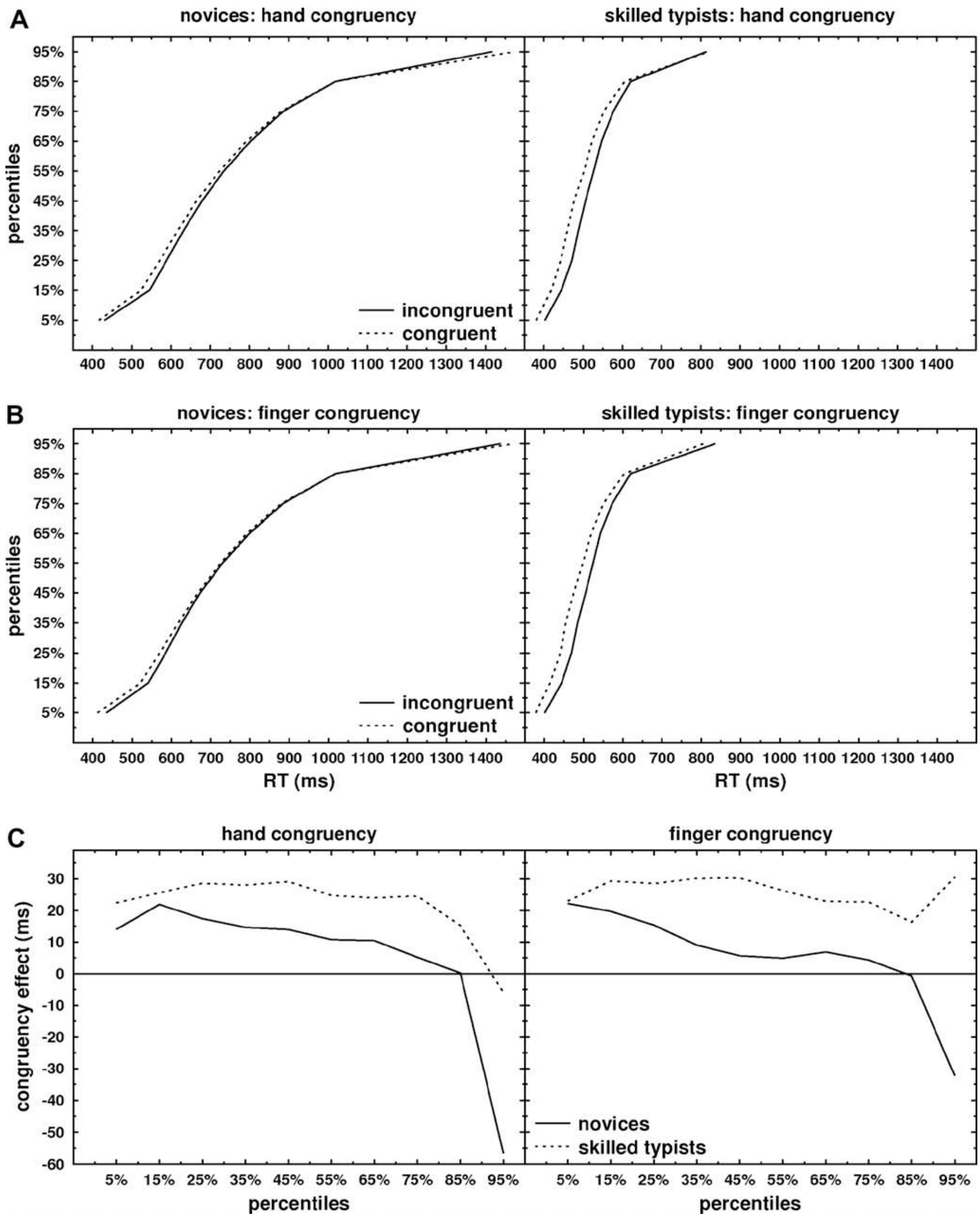

Fig. 1. Distribution analyses depending on congruency condition and expertise level. (A) Response time distribution depending on Hand Congruency. (B) Response time distribution depending on Finger Congruency. (C) Distribution of Net Hand and Finger-Congruency Effects.

Skilled typists committed more errors than novices (7.2% vs. 4.3%), $F(1, 34) = 5.18$, MSE = .027, $p < .05$. The main effect of finger congruency did not reach significance, $F(1, 34) < 1$. When prime and target required the same hand (hand congruency), participants committed less errors than when prime and target required responses with different hands (4.9% vs. 6.7%), $F(1, 34) = 29.11$, MSE = .011, $p < .001$. The congruency effect for the factor finger was 1.1% when the same hand was primed and −.8% when the other hand was primed, $F(1, 34) = 8.89$, MSE = .003, $p = .01$.

The interaction finger congruency × expertise was not significant, $F(1, 34) < 1$. The interaction hand congruency × expertise was significant, $F(1, 34) = 11.56$, MSE = .004, $p < .01$. The hand congruency effect amounted to 3% for experts and to .7% for novices. The significant three-way interaction finger × hand × expertise indicated that for experts the effect of finger congruency amounted to 2.4% error difference when prime and target required the same hand, while the finger-congruency effect was −1.5% for hand incongruency. For novices the effect of finger congruency was not altered by the factor hand congruency (finger-congruency effect of −.2% for same hand and −.2% for different hand), $F(1, 34) = 8.09$, MSE = .003, $p < .01$.

Table 2
Percentage of errors and (standard errors) for skilled typists and novices split by hand congruency and finger congruency.

	Hand		
	Congruent	Incongruent	Hand congruency
Typists			
Finger			
Congruent	4.5 (1.0)	9.5 (1.3)	5.0
Incongruent	6.9 (1.2)	8.0 (1.1)	1.1
Finger congruency	2.4	−1.5	
Novices			
Finger			
Congruent	4.1 (.7)	4.8 (.9)	.7
Incongruent	3.9 (.9)	4.6 (.8)	.7
Finger congruency	−.2	−.2	

3.3. Prime visibility

To assess prime visibility, the signal detection measure d' (Tanner & Swets, 1954) was computed separately for typists and novices. Participants were asked if prime and target were the same letter or not in the just-seen trial. If participants answered correct and prime and target were indeed the same letters, this was considered a hit. If participants answered incorrect although prime and target had in fact been the same letters, this was considered a false alarm. If the hits or false alarms proportion of a participant was zero or one it was corrected using the log-linear rule (Goodman, 1970; cited according to Hautus, 1995).

The discrimination measure for skilled typists was $d' = .47$ and deviated significantly from 0, $t(11) = 3.83$, $p < .01$. For the novices it was $d' = .20$ and differed significantly from 0, $t(23) = 3.04$, $p < .01$. The d' values of skilled typists and novices differed significantly, $t(34) = -2.18$, $p < .05$.

To test whether the observed congruency effects were related to prime visibility, we conducted regression analyses as proposed by Draine and Greenwald (1998) (see also Greenwald, Draine, & Abrams, 1996; Greenwald, Klinger, & Schuh, 1995). Therefore, we computed individual d' values as well as mean RTs for each congruency condition (finger and hand congruency). Hand-priming and finger-priming indices were computed for each participant, with index = 100 × (RT incongruent − RT congruent)/RT congruent.

The individual congruency indices (hand and finger congruency) were regressed onto the individual d' value of each participant separately for the skilled typists and the novices. We tested whether the intercept and the slope deviated significantly from 0. An intercept larger than 0 indicates that a congruency effect also occurs with zero visibility. If the slope does not differ from 0, this indicates that the congruency effect does not increase with visibility.

For the skilled typists the regression of the hand-congruency index on d' revealed a significant intercept of 2.9, $t(11) = 2.79$, $p < .05$. The correlation between d' and the priming index did not reach significance, $r = .33$, $F(1, 10) = 1.2$, $p = .30$. The regression of the finger-congruency index on d' revealed a significant intercept of 3.6, $t(11) = 3.35$, $p < .01$. The correlation between d' and the priming index did not reach significance, $r = .05$, $F(1, 10) < 1$.

For the novices the regression of the hand-congruency index on d' revealed a non-significant intercept of .8, $p > .22$ The correlation between d' and the priming index did not reach significance, $r = .28$, $F(1, 23) = 1.84$, $p > .18$. The regression of the finger-congruency index on d' revealed a non-significant intercept of .42, $p > .36$. The correlation between d' and the priming index did not reach significance, $r = .16$, $F(1, 23) < 1$.

4. Discussion

The first question explored in the present study was whether masked primes have an effect on RTs when participants respond with six different keys. The answer is clear: Yes they do. To our knowledge this is the first demonstration of masked priming in a choice RT task with six response alternatives. So far, masked priming has mostly been shown with two response alternatives (e.g., Dehaene et al., 1998; Klotz & Neumann, 1999). We are aware of only two studies that demonstrated masked priming with more, namely four, response alternatives (Eimer, Schubö, & Schlaghecken, 2002; Schlaghecken et al., 2006; for an unsuccessful attempt to demonstrate masked priming with more than two response alternatives see Wolff, 1997, cited in Ansorge, Klotz, & Neumann, 1998). In contrast to these studies, the design of the present study allowed us to investigate the possible dependence of hand as well as fingers in regard to the influence of masked primes.

The second issue was prompted by results of pre-cueing studies that reported an influence of pre-information about the response hand or the response finger on RTs. These studies suggested a parameter-based representation of manual responses (Miller, 1982; Reeve & Proctor, 1984; Ulrich et al., 1998; Wild-Wall, Sangal, Sommer, & Leuthold, 2003). We examined whether this parameter-based representation is reflected in masked priming as well. Furthermore, we wanted to explore whether overlap regarding one of the two parameters suffices for response facilitation or whether responses need to share both parameters. Again, the overall picture is clear. Even when prime and target response share only one parameter (hand or finger) there is some facilitation compared to a situation where primed and required responses share no features at all.

This result has quite practical consequences. The vast majority of priming studies used 2 choice reaction time tasks with the left and right index finger. Our results suggest that in this case the response congruency effects might be smaller than ideal, because both responses share the same finger-parameter. Hence, even when responses are "incongruent" regarding the hand they are still "congruent" regarding the finger. Our results suggest that congruency effect might be larger for a response mapping that requires responding with one finger of the left hand and with another finger of the right hand. Currently there is no evidence that our results transfer to a situation in which one parameter suffices (e.g., hand) to discriminate between the response. However, if this turns out to be correct, this would be an important finding because masked congruency effects are typically small (between 5 and 20 ms). Thus, several reports of non-significant effects might turn out to be reliable, simply when tested with two more dissimilar response alternatives.

Overlap of prime- and target responses regarding the hand turned out to be somewhat more beneficial than overlap regarding the fingers. Possibly this result reflects the fact that the hand-parameter can be accessed before the finger-parameter but not vice versa, although the emerging data pattern regarding this issue was less clear than optimal (Miller, 1982).

Please note that masked priming effects may likewise be interpreted in terms of the polarity correspondence principle as proposed by Proctor and Cho (2006). According to the polarity correspondence principle, RTs are faster when polarities correspond than when they do not correspond. In the present study polarity correspondence may apply to hand, finger, or both. Our results revealed fastest responses, when both, finger and hand were congruent (i.e., had corresponding polarities) whereas less similarity between hand and/or finger polarities for prime and target let to slower responses. Note, however, that the polarity correspondence principle explains correspondence effects for binary choice RT tasks and bipolar features. Thus, one would need to extend the principle to fit the present study as we have six different stimuli mapped onto six response alternatives whereby the feature finger has three specifications (index, middle, and ring finger).

The third question concerned the role of expertise. Although there is some research on the role of practice within an experiment (Kiesel, Berner, & Kunde, 2008; Schlaghecken et al., 2008), the issue of more extended pre-experimental practice (i.e., expertise) appears to be neglected in research on masked priming. A recent study by Kiesel et al. (2009) showed that expert chess players but not chess novices were able to extract from masked chess configuration whether this was a checking configuration or a nonchecking configuration. The present study furthered the main conclusion of that study that expertise for a certain stimulus domain is a crucial constraint for masked priming effects. Yet, in the present study expertise did not concern the stimulus material as such. Conceivably, letters are highly familiar to practiced as well as less practiced typists. In contrast, skilled typists and novices differ regarding practice with the specific mapping of stimuli and required motor actions. Hence, masked priming is constrained by pre-experimental expertise, not only regarding the stimulus material and the necessary cognitive operations, but regarding the requested S–R translation.

Expertise effects came across not only as overall enlarged congruency effects in experts, but as a somewhat different priming pattern. Specifically, overlap of primed and requested response regarding the finger facilitated performance in experts but not, or at least not significantly, in novices. Possibly, this is a consequence of the generally smaller priming effects in novices that give fewer chances for "collateral" priming of responses that are not identical but merely similar to each other.

It should be noted that high amounts of "collateral" priming of similar responses is not necessarily helpful when it comes to actual typing, because it might give rise to typos. Therefore it seems not too far fetched to assume that expert typists develop means to counteract collateral activation of responses that are somehow similar but not identical to the response that is eventually requested. This speculation has to be tested by future research. A way to do so might be to use an S–R mapping where letters can be responded to by either of two homologous fingers without counting as error (e.g., respond to F and J with an index finger, irrespective of the hand). This might discourage mechanisms that suppress collateral activation of homologous fingers and possibly result in much larger differences in response priming between experts and novices than observed here.

Finally, it seems necessary to rule out an alternative explanation for the results reported here. In the experiment, primes and targets were congruent in 50% of all cases. In the other 50% primes and targets were incongruent. Incongruency in this case can be divided in three sub-groups that occurred with different frequencies. There were partially congruent trials containing finger-congruent/hand-incongruent (20%) and finger-incongruent/hand-congruent trials (20%), and fully incongruent trials that were finger-incongruent/hand-incongruent (10%). In this design, the primes were predictive because each prime predicted the to-be-used hand with 70% accuracy, and the to-be-used finger (irrespective of finger) with 60% accuracy. Recent observations revealed that the magnitude of masked priming effects depends on the proportions of congruent and incongruent trials (Bodner & Dypvik, 2005; Klapp, 2007). One might assume that the observed patterns of hand and finger-congruency effects are influenced by this different pattern of predictiveness for 'fully congruent' vs. 'partially congruent' vs. 'incongruent' trials.[1]

To rule this alternative explanation, we conducted a second experiment with 18 skilled typists (mean age: 24.7, sd = 4.3; mean number of correct keystrokes in 5 min were 1344, sd = 413, with minimum = 855 and maximum = 2545), in which primes were followed equally often by each target so that they were non-predictive for hand or finger. Otherwise, the exper-

[1] We thank Friedericke Schlaghecken for pointing out this alternative explanation.

iment was the same as the experiment reported above. The results fully support the interpretation of the first experiment. We observed two significant main effects (finger-congruency, $F(1, 17) = 9.00$, $p < .01$ and hand congruency, $F(1, 17) = 19.81$, $p < .001$) and a marginally significant interaction ($F(1, 17) = 3.91$, $p > .06$). The congruency effects were 9 ms and 13 ms for the finger- and hand congruency, respectively (as compared to 18 ms and 18 ms for the typists in the first experiment). We conclude that although the congruency effects are larger in Experiment 1 and the proportion of congruent trials influences the size of the congruency effects, an equal ratio of congruent and incongruent trials does not prevent congruency effects.

To conclude, the present study demonstrated congruency effects by masked primes in a task with more than two response alternatives. The results show that prime-induced motor activation spreads to responses that share common motor parameters. The size and nature of the masked collateral priming is shaped by pre-experimental expertise in the respective S–R translation.

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Correspondence concerning this article should be addressed to Alexander Heinemann, Institut für Psychologie, Emil-Figge-Str. 50, 44227 Dortmund, Germany. We thank Friedericke Schlaghecken, James Enns, and an anonymous reviewer for helpful comments on an earlier version of the article.

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