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Opposing influences of global and local stimulus-hand proximity on crosstalk interference in dual tasks

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Abstract

In contrast to traditional dualistic views of cognition, visual stimulus processing appears not independent of bodily factors such as hand positioning. For example, reduced crosstalk between two temporally overlapping tasks has been observed when the hands are moved into the attentional window alongside their respective stimuli (i.e., establishing global stimulus-hand proximity). This result indicates that hand-specific attentional processing enhancements support a more serial rather than parallel processing of the two tasks. To further elucidate the nature of these processing modulations and their effect on multitasking performance, the present study consisted of three interrelated crosstalk experiments. Experiment 1 manipulated global stimulus-hand proximity and stimulus-effect proximity orthogonally, with results demonstrating that hand proximity rather than effect proximity drives the crosstalk reduction. Experiment 2 manipulated the physical distance between both hands (i.e., varying local stimulus-hand proximity), with results showing weak evidence of increased crosstalk when both hands are close to each other. Experiment 3 tested opposing influences of global and local stimulus-hand proximity as observed in Experiment 1 and 2 rigorously within one experiment, by employing an orthogonal manipulation of these two proximity measures. Again, we observed slightly increased crosstalk for hands close to each other (replicating Experiment 2); however, in contrast to Experiment 1, the effect of global stimulus-hand proximity on the observed crosstalk was not significant this time. Taken together, the experiments support the notion of hand-specific modulations of perception-action coupling, which can either lead to more or less interference in multitasking, depending on the exact arrangement of hands and stimuli.

Keywords

multitasking; backward crosstalk; embodied cognition; peri-personal space; hand posture effect; perception-action coupling

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Introduction

Advocates of *embodied cognition* argue that the nature of the human mind and its cognitive operations essentially depend on the organism's physical body and its dynamic interaction with the environment (e.g., Newen et al., 2018; Shapiro, 2019). Consistent with this view, cognitive task performance is often altered when stimuli are presented relatively close to the hands as opposed to relatively far from the hands, suggesting that visual processing is altered in peri-hand space (for reviews, see Goodhew et al., 2015; Taylor et al., 2015). Understanding how exactly vision is altered near the hands is not only important for theoretical reasons. Rather, considering that humans increasingly interact with digital technologies in an embodied manner (think, for example, of hand-held devices), the field appears to be a promising avenue for

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bridging the gap between basic psychological research and more applied cognitive science (e.g., human–machine interaction).

In a typical experiment investigating the so-called hand-nearness effect, participants perform a computer-based task in the lab with their hands placed on response buttons either close to the stimulus, for example, located directly at the screen (proximal condition), or far from the stimulus, for example, located on a board far from the screen (distal condition). In a seminal paper, Abrams et al. (2008) demonstrated that participants were slower to disengage attention from successively processed items when the hands were located near the display in a visual search task. Furthermore, these authors also report a reduced inhibition of return effect and a more pronounced attentional blink effect for the proximal condition. Taken together, these results suggest that items in peri-hand space are associated with a more in-depth visual analysis, potentially resulting from increased attentional resources devoted to these items. Performance improvements observed with signal detection (Reed et al., 2006) and simple visuomotor tasks (e.g., Hari & Jousmäki, 1996) provide further evidence for a general visual processing benefit in peri-hand space.

Functional aspects of altered stimulus processing in peri-hand space

From a functional perspective, such improved processing of items near the hands might be adaptive, as these items often afford to be integrated into the planning of an upcoming action (Taylor & Witt, 2014) or require fast reflexes for defensive purposes (Graziano & Cooke, 2006). Consistent with this, neurophysiological data from animal studies which recorded the firing rate of neurons representing the space around the hands—for example, in ventral premotor cortex—report gradually increasing firing rates of neurons with decreasing stimulus-hand distance (e.g., Graziano et al., 1994; Graziano & Gross, 1998). On a more general level, these observations support theoretical approaches assuming action and perception to be highly interdependent processes rather than independent modules (e.g., Gibson, 1977; Hommel et al., 2001; Neumann, 1987; Prinz, 1990; Rizzolatti et al, 1987).

Nevertheless, the view that the effects of hand nearness on task performance are fully mediated by a general and non-specific enhancement of stimulus processing has not remained unchallenged. Rather, for instance, the *visual pathway hypothesis* states that visual processing in peri-hand space differs qualitatively by being biased towards the action-oriented dorsal processing stream (Gozli et al., 2012). Recall that the magnocellular neurons in the dorsal stream are distinguished by higher temporal resolution from the parvocellular neurons in the ventral stream (Goodhew et al., 2015). Hence, in accordance with the visual pathway hypothesis, recent studies reported improved task performance in peri-hand space for a temporal, but not a spatial gap detection task (Gozli et al., 2012; see also Abrams & Weidler, 2014; Goodhew et al., 2013).

Yet, another line of research has provided evidence that the effects of stimulus-hand proximity on task performance do not only result from enhanced bottom-up processing—be it general or pathway-specific—but also from top-down factors such as increased cognitive control engagement. For example, Liepelt and Fischer (2016) observed reduced interference from task-irrelevant location information in a cognitively demanding number-judgement Simon task for hand-proximal compared with hand-distal stimuli. Analogous observations have been reported for a flanker task (Weidler & Abrams, 2014) and a non-spatial Stroop task (Davoli et al., 2010). Taken together, these conflict-task studies suggest that stimulus-hand proximity might facilitate the act of volitionally focusing on the task-relevant information (e.g., the number identity in a number Simon task) for response selection while ignoring or inhibiting the task-irrelevant information (but see Wang et al., 2014, 2021).

Effects of stimulus-hand proximity on human multitasking performance

Most of these studies investigated hand proximity effects in the context of relatively simple single-task conditions, while many real-world settings require humans to coordinate complex multitasking situations involving the concurrent processing of multiple stimuli in view with two different hands. It is therefore not surprising that recent research has pointed out the importance of experimentally addressing the influence of stimulus-hand proximity on control demands in human multitasking as well (e.g., Fischer & Liepelt, 2020; Hosang et al., 2018).

In a classic dual-tasking setting, the psychological refractory period (PRP) approach, two stimuli requiring separate responses are presented in close succession (Pashler, 1994; Welford, 1952; see Fischer & Janczyk, 2022, for a recent review). In such a situation, the processing of each component task tends to be influenced by aspects of the other task. For example, responses are typically slower and more error prone when both stimuli call for opposite responses than when they call for the same response (Hommel, 1998; for other examples, see Fischer et al., 2007; Janczyk et al., 2014). Such crosstalk interference effects can be subdivided into backward crosstalk (*backward crosstalk effect, or BCE*) and forward crosstalk, depending on whether the performance in Task 1 is influenced by aspects of Task 2 or performance in Task 2 is influenced by aspects of Task 1, respectively (see Koob et al., 2021, for a computational approach to crosstalk effects). In any case, crosstalk effects are usually interpreted to indicate that separating the response selection processes of the two tasks is only partially achieved, potentially because such task-shielding puts great demands on cognitive control under dual-task requirements (Fischer & Hommel, 2012; Logan & Gordon, 2001).

To investigate how task-shielding is affected by stimulus-hand proximity, Fischer and Liepelt (2020) employed a standard crosstalk paradigm where the response buttons were located either at the screen (proximal condition) or in the lap (distal condition). Importantly, the literature suggested two plausible predictions concerning the effect of this manipulation on the amount of crosstalk interference. On one hand, a general attentional processing benefit for all stimuli in the attentional field between both hands (cf. Abrams et al., 2008; Tseng & Bridgeman, 2011) would imply more integrative processing of the two stimuli and thus imply increased crosstalk for the proximal than in the distal condition. On the other hand, the possibility of a hand-specific processing benefit (cf. Bush & Vecera, 2014) would support more separate processing of the two stimuli and thus imply reduced crosstalk for the proximal condition. The results were clear-cut: the amount of (backward) crosstalk was reduced for the proximal condition, and this reduction was even more pronounced in an additional experiment where only one hand instead of two hands was located near the stimuli in the proximal condition. Thus, Fischer and Liepelt (2020) speculated that the spatial proximity of a stimulus with its corresponding response hand might lead to a stronger coupling of perceptual with response-related codes for each single hand and task (Hommel et al., 2001; Prinz, 1990), hence leading to a better separation of the two stimulus-response translation processes in the dual-tasking context.

Stimulus-hand proximity versus stimulus-effect proximity in human multitasking

The present study aimed at addressing some outstanding questions which directly follow from the assumption that stimulus-hand proximity facilitates the stimulus-response translation near each hand. A first goal was to test for the role of action effects as a potential contributor to this facilitated stimulus-response (S-R) binding. From the action control literature, it is well known that the anticipated sensory consequences of an action contribute to the response selection process (*ideomotor principle*, cf. Greenwald, 1970; Hommel et al., 2001; James et al., 1890; Janczyk et al., 2022; Kunde, 2001). For instance, Hommel (1993) introduced visual action effects to an auditory Simon task (left/right responses to high/low pitched tones randomly presented to the left and right ear). Crucially, when the visual action effects appeared on the side opposite to the required response, an inverted Simon effect emerged: participants performed better when the stimulus position was incongruent with the response side (hence congruent with the effect side), indicating that stimulus-effect compatibility rather than stimulus-response compatibility contributes as a relevant factor in determining response facilitation. For related observations in more applied contexts, such as tool use, see Janczyk et al. (2012; see also Kunde et al., 2007; Müsseler & Skottke, 2011; Sutter et al., 2013; and for opposing evidence, see Janczyk et al., 2019).

Importantly, these observations have implications for the studies that employed the standard manipulation of placing the hands either at the screen or far from the screen (e.g., in the lap) to realise the proximal and distal conditions, respectively. Albeit being a common procedure in most such studies, this manipulation confounds hand proximity and effect proximity, since moving the hands closer to the stimuli also moves the body-related action effects (e.g., sensing and seeing the moving finger; see Pfister, 2019) closer to the stimuli. Agents monitor their responses (Jentzsch & Dudschig, 2009) as well as the body-external effects of these responses (Wirth et al., 2018; see Janczyk & Kunde, 2020, for a review on the role of action effects on multitasking). Focusing attention on a smaller area in space for processing task-relevant stimuli and response monitoring in a proximal condition might render inadvertent processing of currently task-irrelevant stimuli less likely as compared to a far response condition, in which a more expanded distribution of attention is conceivably adopted to capture both stimuli and monitored responses. This accords with the speculation of Fischer and Liepelt (2020) that moving the hands into a shared attentional field together with the stimuli makes S-R translation near each hand more effective. In any case, the available data do not inform whether this near-hand effect is driven by hand proximity or rather by effect proximity. To address this question, Experiment 1 manipulated both factors orthogonally within a typical dual-task crosstalk paradigm (cf. Fischer et al., 2014, 2018; Fischer & Hommel, 2012).

Global versus local stimulus-hand proximity in human multitasking

Beyond this, and as a second goal, we aimed at investigating the spatial scope of the attentional processing enhancements presumably underlying the facilitated S-R translations near each hand. Importantly, many behavioural studies investigating the effects of stimulus-hand proximity on human task performance employed only two conditions; as noted above, the proximal and distal conditions are typically realised by placing the response buttons either at the screen or far from the screen, respectively. Here, stimulus-hand proximity is implicitly conceptualised as a binary measure; hands are either fully inside or fully outside a shared attentional window with the hands. In our terminology, we will refer to this dichotomous type of stimulus-hand proximity as *global proximity*. On the contrary, by *local proximity*, we refer to the physical variation of stimulus-hand proximity at any given level of global proximity. For instance, Hari and Jousmäki (1996) demonstrated that participants were faster to respond when visual stimuli were projected directly onto their fingers than a few centimetres away from their fingers. Similarly, Serino et al. (2015) observed a gradual facilitation effect on response times (RTs) with a gradual increase of stimulus-hand proximity within the visual field (for other examples of experiments deviating from the typical binary conceptualisation of peri-hand space, see Davoli & Brockmole, 2012; Murchison & Proctor, 2015).

These observations are consistent with the neuroscientific literature suggesting that peri-hand space might be conceptualised as an action-related field that is graded with proximity rather than a dichotomous "in-or-out bubble" (Bufacchi & Iannetti, 2018). In fact, as these authors point out, many of the original physiological studies on peri-personal space, which later inspired the dichotomous setups used in more cognitive human behavioural studies, showed a continuous increase of neural responses with continuously increasing proximity (e.g., Duhamel et al., 1998; Graziano et al., 1994; Rizzolatti et al., 1981).

To the best of our knowledge, the influence of local stimulus-hand proximity on dual-tasking performance has not yet been investigated. Rather, as noted above, most behavioural studies including dual-tasking studies such as Fischer and Liepelt (2020) and Hosang et al. (2018) implicitly equate stimulus-hand proximity with global proximity. However, the distinction between global and local proximity might be especially crucial in dual-tasking situations. For example, even though placing the hands at the screen might support more separate processing of the two stimuli, moving the hands closer together at the screen might also support a more integrative processing, as soon as the peri-hand spaces of the two hands overlap to a substantial degree. Accordingly, Experiment 2 will test the hypothesis of increased crosstalk in the locally proximal condition by manipulating the physical distance between hands and stimuli horizontally in a standard crosstalk paradigm. Finally, Experiment 3 will investigate opposing influences of local and global proximity within one single experiment, by combining both factors orthogonally.

Experiment 1

The goal of this first experiment was twofold. First, we aimed at replicating the reduced BCE for the global-proximal condition compared with the global-distal condition reported by Fischer and Liepelt (2020). Second, we aimed at investigating whether this effect is rather driven by (global) stimulus-hand proximity or by stimulus-effect proximity. To that end, we employed the same type of crosstalk paradigm which was used in the original study and participants had to classify two successively presented numbers as odd or even. Importantly, in the present experiment, effect proximity and global hand proximity were manipulated orthogonally. Thus, in case the effect is driven by hand position, one should observe a modulation of the BCE by hand proximity, but not effect proximity, while the reverse should be true in case of an effect proximity–driven effect. Hence, in statistical terms, our hypotheses focused on the two-way interactions of both global hand proximity with compatibility and effect proximity with compatibility on RTs and/or percentages error (PE) in Task 1.

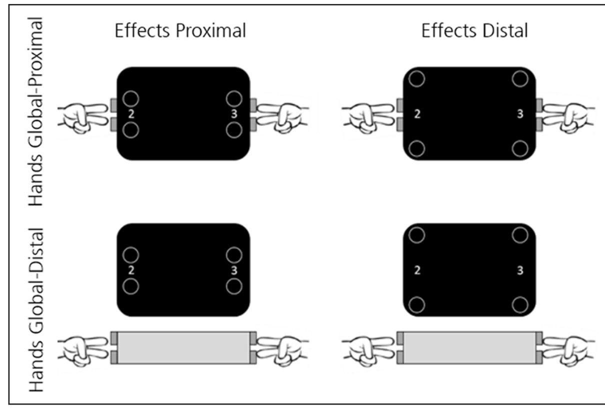

Figure 1. Schematic illustration of the orthogonal manipulation of hand and effect proximity in Experiment 1.

Methods

Participants. Thirty-two adult participants from the Würzburg (Germany) area participated in the experiment. All participants reported normal or corrected-to-normal vision and provided written informed consent prior to data collection.

Stimuli and apparatus. For a schematic illustration of the experimental designs, see Figure 1. Stimulus presentation and response collection were controlled by a standard PC connected to a 17-in. CRT monitor. Stimuli were the digits 2, 3, 7, and 8 in Task 1 (S1), and 1, 4, 6, and 9 in Task 2 (S2). S1 and S2 were presented in white against a black background, vertically centred and at the left (S1) and right (S2) edge of the screen (see Figure 1 for an illustration). Above and below both stimulus positions, white outlines of circles appeared as placeholders for the effects. They were also placed at the edge of the screen, either close to the stimuli (proximal effect distance) or further apart (distal effect distance). Responses were given via external response keys that were placed at the edge of the screen close to the stimuli (responses R1 and R2 in Task 1 and 2, respectively), and the circle outlines were filled with white colour as action effects (effects E1 and E2 in Task 1 and 2, respectively).

Responses were collected with four custom-built response keys which were differently positioned depending on the hand distance condition: In the proximal hands

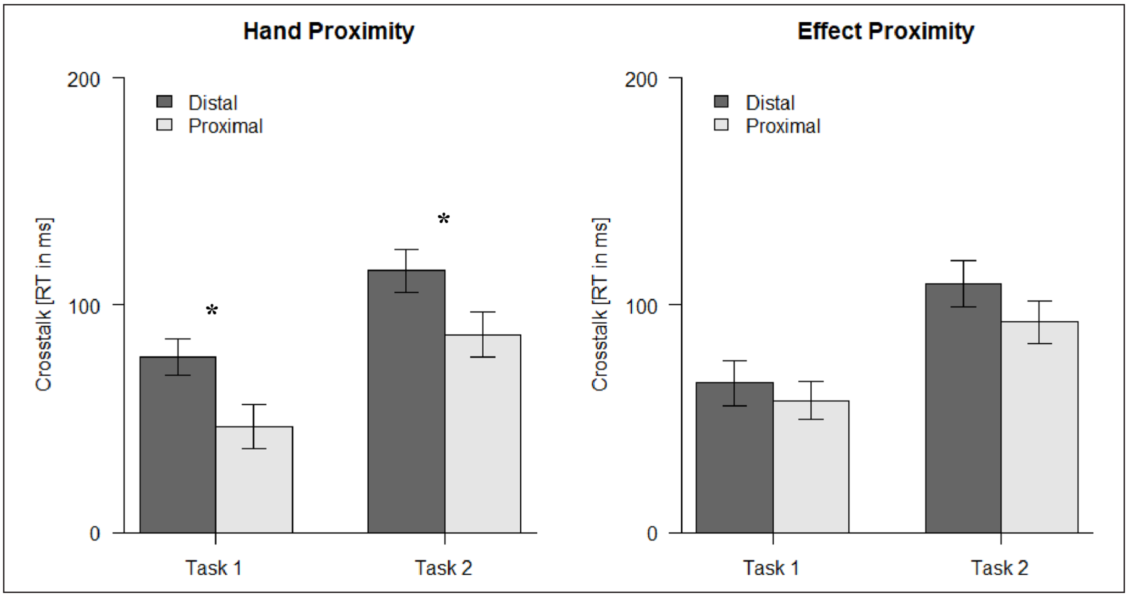

Figure 2. Experiment 1: Task 1 and Task 2 crosstalk effects in RTs as a function of global hand proximity (left panel) and effect proximity (right panel). **p* < .05.

condition, two keys each were attached to the left and right side of the monitor. (Participants could place their elbows on small pillows to make this position comfortable.) In the distal hands condition, the response keys were attached to a wooden block of the same length as monitor width, which was placed on the participants' knees. R1s were given with the left index finger and middle finger, and R2s were given with the right index finger and middle finger.

Task and procedure. In both tasks, participants were to indicate with their response whether the digit was odd or even. Each trial began with the onset of the four effect locations and a centred fixation cross (250 ms). The fixation cross then disappeared for 250 ms, and S1 set on. Following an additional stimulus-onset asynchrony (SOA) of 40 ms, S2 set on. A trial was cancelled after 4,000 ms if not both responses were given within this time limit. If necessary, error feedback ("too slow," "wrong response in Task 1/2") was provided for 1,000 ms, and the next trial started after a blank inter-trial interval (ITI) of 1,000 ms.

All four S1 were combined equally often with all four S2, and these 16 combinations were repeated eight times, yielding 128 trials per block, presented in random order. Participants started the experiment with an unanalyzed practice block of 20 randomly drawn trials followed by four experimental blocks (one for each combination of hand and effect distance).

Participants were tested individually in one single session lasting about 40 min. Instructions were provided in written form on-screen and emphasised speeded responses while maintaining errors at a low level. The category-response mappings in both tasks were counterbalanced across participants. Furthermore, four different orders of hand and effect proximity were implemented and counterbalanced across participants: Blocks 1 and 2 were hand proximal and Blocks 3 and 4 hand distal (or vice versa), and within Blocks 1 and 2, and 3 and 4, the first block was effect proximal and the second effect distal (or vice versa).

Statistical analysis. Compatibility was based on the classification of both stimuli: if both stimuli were odd or both stimuli were even, a trial was compatible, and otherwise, it was incompatible. For both RT and PE analysis, only trials with both RT1 and RT2 between 150 and 3,000 ms were considered. Furthermore, for RT analyses, only entirely correct trials were considered. Mean RTs and mean PEs were analysed with a $2 \times 2 \times 2$ repeated-measures analysis of variance (ANOVA) with the factors compatibility (compatible vs incompatible), (global) hand proximity (proximal vs distal), and effect proximity (proximal vs distal).

Results

The main results of this Experiment for RT and PE are visualised in Figures 2 and 3, respectively.

Mean RT

Task 1. The main effect of compatibility was significant with slower responses in incompatible compared with compatible trials (906 ms vs 844 ms), $F(1, 31) = 48.36$, $p < .001$, $\eta_p^2 = .61$. Both the main effect of hand distance and the main effect of effect distance were significant, $F(1, 31) = 5.46$, $p = .026$, $\eta_p^2 = .15$, and $F(1, 31) = 4.59$, $p = .040$, $\eta_p^2 = .13$, respectively. For both hand and effect proximity,

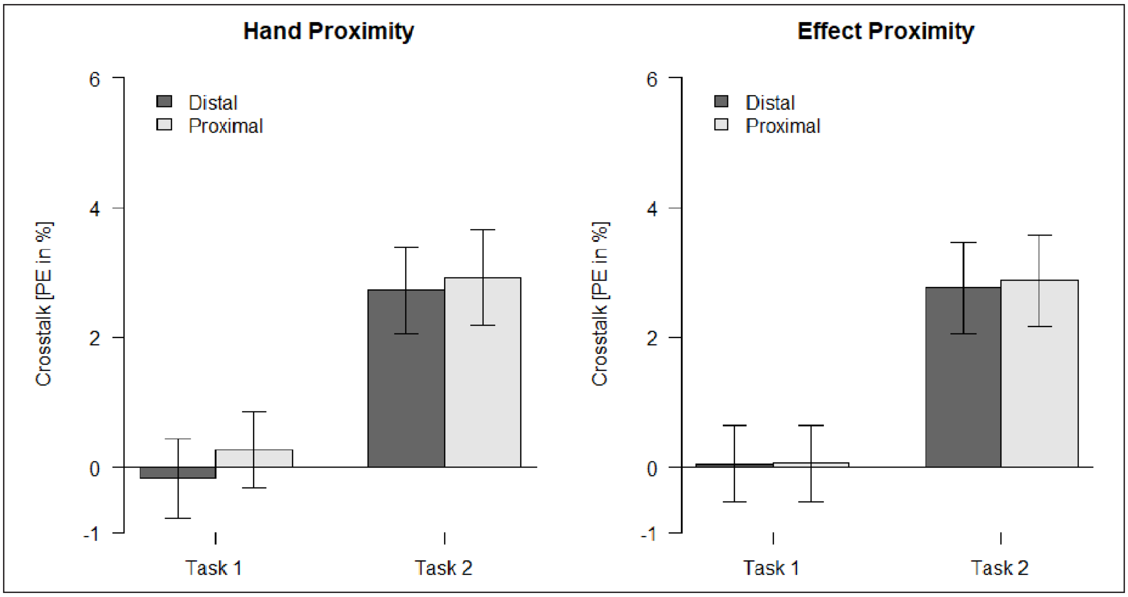

Figure 3. Experiment 1: Task 1 and Task 2 crosstalk effects in PEs as a function of global hand proximity (left panel) and effect proximity (right panel).

responses were faster in the proximal compared with the distal condition (858 ms vs 890 ms for hand proximity, and 862 ms vs 886 ms for effect proximity, respectively). Most importantly, the interaction of hand proximity and compatibility was significant with a smaller compatibility effect with proximal hands, $F(1, 31)=6.40$, $p=.017$, $\eta_p^2=.17$. Specifically, the BCE was 47 ms for the proximal hand condition and 76 ms for the distal hand condition. Effect proximity, in contrast, did not modulate the crosstalk effect, $F(1, 31)=0.50$, $p=.484$, $\eta_p^2=.02$. Also, neither the interaction between hand and effect proximity nor the three-way interaction were significant, $F(1, 31)=0.27$, $p=.609$, $\eta_p^2=.01$, and $F(1,31)=0.24$, $p=.626$, $\eta_p^2=.01$, respectively.

Task 2. Responses were slower in incompatible trials compared with compatible trials (1,140 ms vs 1,042 ms), $F(1, 31)=106.98$, $p<.001$, $\eta_p^2=.78$. The main effect of hand distance was not significant, $F(1, 31)=0.26$, $p=.617$, $\eta_p^2=.01$. The main effect of effect distance was significant, $F(1, 31)=6.01$, $p=.020$, $\eta_p^2=.16$, reflecting faster responses with proximal effects compared with distal effects (1,071 ms vs 1,109 ms). Effect distance did not modulate the compatibility effect, $F(1, 31)=3.41$, $p=.074$, $\eta_p^2=.10$. However, the interaction between hand proximity and compatibility approached significance, $F(1, 31)=4.11$, $p=.051$, $\eta_p^2=.12$, reflecting a smaller crosstalk effect with hands proximal compared with hands distal (85 ms and 111 ms, respectively). Furthermore, the interaction between hand and effect proximity was significant, $F(1, 31)=10.40$, $p=.003$, $\eta_p^2=.25$, reflecting a larger net effect of effect proximity for the hands proximal compared with the hands distal condition (95 ms vs 19 ms). The three-way interaction was not significant, $F(1, 31)<0.01$, $p=.971$, $\eta_p^2<.01$.

Mean PE

Task 1. PEs varied between 3.1% and 3.8% per condition. In the corresponding ANOVA, no effect reached significance, all $F\text{s}\leq 1.02$, all $p\text{s}\geq .321$.

Task 2. PEs varied between 3.5% and 7.6%. More errors were committed in incompatible compared with compatible trials (7.0% vs 4.2%), $F(1, 31)=12.21$, $p=.001$, $\eta_p^2=.28$. All other $F\text{s}\leq 2.83$, all $p\text{s}\geq .102$.

Discussion

In this dual-task crosstalk experiment, we varied the distance of both response hands and action effects to the centrally presented stimuli. The important main result is that the hand distance manipulation fully replicated the results reported by Fischer and Liepelt (2020): The compatibility effect in Task 1 (BCE) was reduced when the hands were located near the stimuli compared with when they were located far from the stimuli. In addition, the compatibility effect in Task 2 (forward crosstalk) was also reduced in the hand-proximal condition. Effect proximity exerted a main effect on both Task 1 and Task 2 RTs, with faster responses in case of near effects, suggesting that the manipulation exerted an influence on performance in principle. Interestingly, for Task 2, this facilitating effect of effect proximity was attenuated for the hand-distal as compared with the hand-proximal condition. One possible post hoc explanation for this might be that a narrower attentional focus in the hand-proximal condition has increased the salience of the effect proximity variation. Alternatively, participants might be generally less inclined to construe the visual "effects" as consequences of their motor responses, the more hands and effects are spatially separated, whereby variations of these effects diminish.

Critically, however, effect distance did not significantly affect the size of the BCE. Thus, the present results suggest that the reduced crosstalk for the proximal compared with the distal condition as observed by Fischer and Liepelt (2020) and in the present experiment seems to be driven by stimulus-hand proximity rather than by stimulus-effect proximity. For example, hand-specific processing enhancements might selectively facilitate the stimulus-response translation processes near each hand, leading to a better separation of the two tasks.

In sum, the results from Experiment 1 are consistent with the assumption of hand-specific attentional foci selectively enhancing stimulus processing near each hand. Nevertheless, not much is known about the nature of these attentional foci, as, for example, their spatial scope. As soon as global proximity is established by moving the hands into a shared attention field with the stimuli, does the actual physical distance between the hands and stimuli cause an additional processing alteration? To address this question, a second experiment was carried out.

Experiment 2

To investigate the influence of local stimulus-hand proximity on dual-tasking, we ran a crosstalk experiment in which the hands were located at the screen across conditions (keeping global proximity constant); however, the horizontal distance between the hands and the centrally presented stimuli was varied (hence manipulating local proximity). Again, we employed the same type of crosstalk paradigm which was used in the previous experiment. Participants had to classify two successively presented numbers as odd or even. Crucially, as can be seen in Figure 5, the response buttons were now located at a tilted screen across conditions with the palm of both hands facing downwards, but we manipulated the local proximity by manipulating the horizontal distance between the stimuli and the response buttons. For this scenario, two plausible concurrent hypotheses are viable. On one hand, moving the hands physically closer to the stimuli might enhance the perception-action coupling near each hand, hence supporting a more separate processing of the two tasks. In this case, one should observe a crosstalk reduction for the local-proximal compared with the local-distal condition. On the other hand, under the assumption that peri-hand spaces are action-related fields surrounding the hands graded with proximity (Bufacchi & Iannetti, 2018; Serino et al., 2015), the overlap of these fields in the local-proximal condition should lead to a higher task confusion and hence a more integrative processing of the two component tasks. In this case, one should observe an increased BCE for the local-proximal condition. Hence, in statistical terms, our hypotheses focused on the two-way interaction of local proximity and compatibility on RT and/or PE in Task 1.

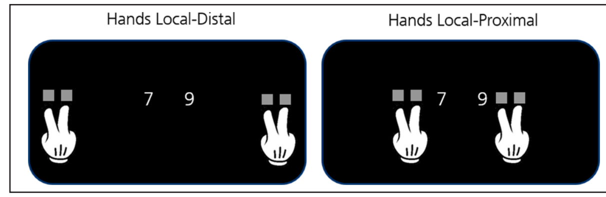

Figure 4. Schematic illustration of the two local proximity conditions in Experiment 2.

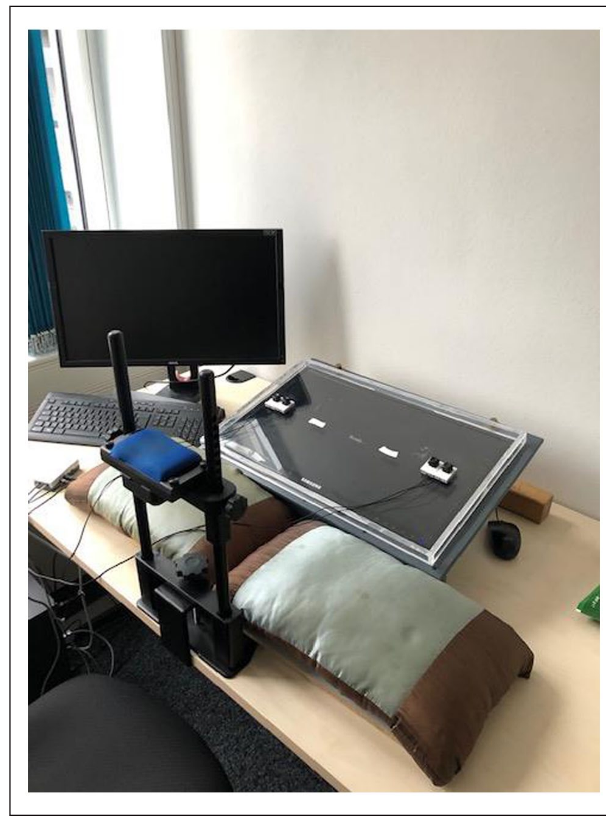

Figure 5. The setup used for Experiments 2 and 3.

Methods

Participants. Thirty-four adult participants from the Cologne (Germany) area participated. All participants reported normal or corrected-to-normal vision and provided written informed consent prior to data collection.

Stimuli and apparatus. For an illustration of the experiment design, see Figure 4, and for a picture of the experimental setup, see Figure 5. Apparatus and stimuli were similar as

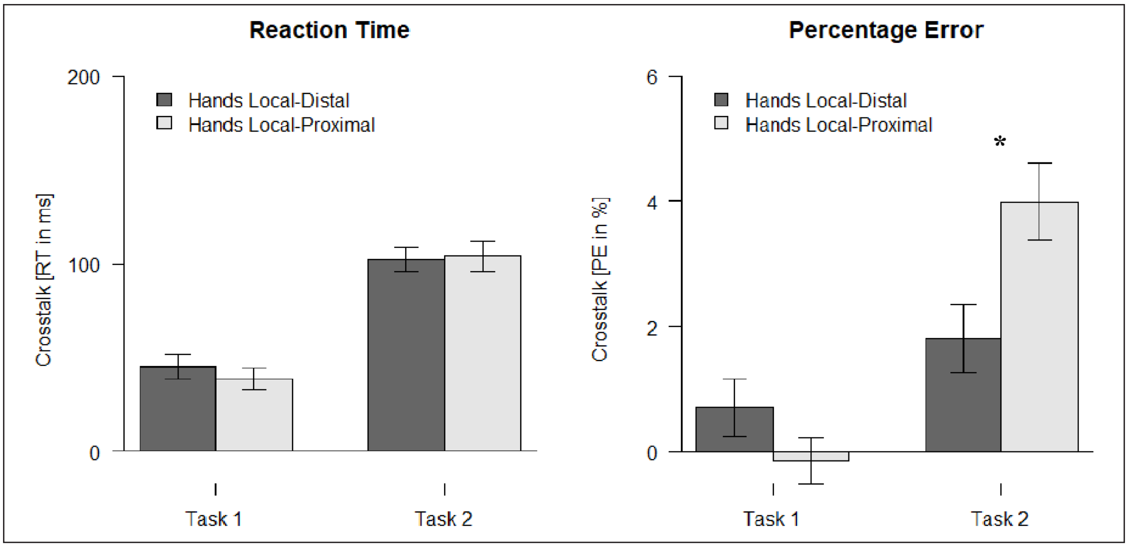

Figure 6. Experiment 2: Task 1 and Task 2 crosstalk effects as a function of local proximity for RT (left panel) and PE (right panel). *p < .05.

in Experiment 1, except for the location of the screen and the response buttons. Specifically, the screen was levelled into a wooden board positioned about 10 cm above the tabletop in 45° angle in front of the participants. Two pairs of custom-made response buttons were placed on the screen, one to the right and one to the left of the centre. In the local-proximal condition, the horizontal distance between the central fixation and the response buttons was 9 cm, while in the distal condition this distance amounted to 20 cm. Participants kept their index and middle fingers on the response buttons with the palms of both hands facing downwards during the experiment and placed their elbows on small pillows to make this position comfortable. Again, R1s were given with left index finger and middle finger, and R2s were given with the right index finger and middle finger. A chin rest was used to ensure a constant viewing distance.

Task and procedure. The course of a single trial was identical to Experiment 1, except for the variable SOAs between S1 and S2 (i.e., 40, 130, 300, 900 ms). All four S1 were combined equally often with all four S2, and these 16 combinations were repeated 4 times (one for each SOA), yielding 64 trials per block, presented in random order. The order of local-proximal and local-distal blocks was counterbalanced between participants; Blocks 1–3 were local-proximal and Blocks 4–6 were local-distal (or vice versa). Hence, participants completed 384 trials in total. Before Block 1 and Block 4, participants completed a test block of 16 randomly drawn trials to get familiar with the task in the respective hand position.

Participants were tested individually in one single session lasting about 40 min. Instructions were provided in written form on-screen and emphasised speeded responses while maintaining error rates at a low level.

Statistical analysis. Data preparation and analysis mirrored Experiment 1. Mean RTs and mean PEs were analysed with a $2 \times 2 \times 4$ repeated-measures ANOVA with the factors compatibility (compatible vs incompatible), local proximity (local-proximal vs local-distal), and SOA (40, 130, 300, 900).

Results

The main results for this experiment are visualised in Figure 6. In addition, RTs and PEs as a function of SOA is given in Figure 7.

Mean RT

Task 1. The main effect of compatibility was significant with slower responses in incompatible compared with compatible trials (795 ms vs 754 ms), $F(1, 33) = 37.03$, $p < .001$, $\eta_p^2 = .53$. The main effect of SOA was also significant, $F(3, 99) = 8.88$, $p < .001$, $\eta_p^2 = .21$, corresponding to a steady decline in RT with increasing SOA, with 792 ms at the shortest SOA and 746 ms at the longest SOA. Furthermore, the interaction of SOA and compatibility was significant as well, $F(3, 99) = 14.35$, $p < .001$, $\eta_p^2 = .30$, corresponding to the well-documented finding of a reduced BCE at longer SOAs (e.g., Hommel, 1998, Experiment 3; Schonard et al., 2020). Specifically, the crosstalk effects were 73 and 1 ms for the shortest and the longest SOA, respectively. However, most important for the present investigation, the interaction effect of local proximity and compatibility was not significant, $F(1, 33) = 0.33$, $p = .569$, $\eta_p^2 = .01$, corresponding to numerically similar BCEs for the proximal (36 ms) compared with the distal (46 ms) condition. Neither the main effect of local proximity, nor the interaction of local proximity

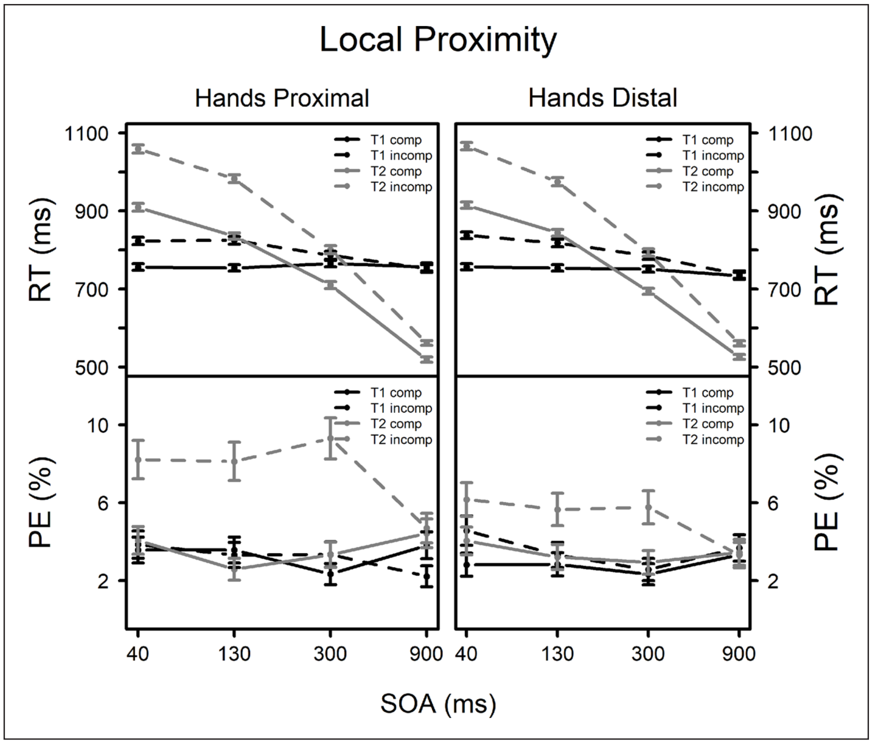

Figure 7. Experiment 2: RT and PE as a function of SOA, compatibility, local proximity, and Task.

and SOA, nor the three-way interaction of all three factors were significant, $F(1, 33)=0.20$, $p=.661$, $\eta_p^2=.01$, $F(3, 99)=1.27$, $p=.288$, $\eta_p^2=.04$, and $F(3, 99)=0.30$, $p=.825$, $\eta_p^2=.01$, respectively.

Task 2. The main effect of compatibility was significant with slower responses in incompatible compared with compatible trials (848 ms vs 745 ms), $F(1, 33)=157.36$, $p<.001$, $\eta_p^2=.83$. The main effect of SOA was also significant, $F(3, 99)=731.80$, $p<.001$, $\eta_p^2=.96$, corresponding to a decline in RT with increasing SOA, namely 986 ms at the shortest SOA and 542 ms at the longest SOA, thus a PRP effect (e.g., Pashler, 1994). Furthermore, the interaction of SOA and compatibility was significant as well, $F(3, 99)=26.47$, $p<.001$, $\eta_p^2=.45$, again corresponding to a larger crosstalk effect at the shorter SOA. For example, the crosstalk effects were 150 and 40 ms for the shortest and the longest SOA, respectively. The main effect of local proximity and the interaction of local proximity and compatibility were not significant, $F(1, 33)=0.01$, $p=.916$, $\eta_p^2=.01$, and $F(1, 33)=0.20$, $p=.654$, $\eta_p^2=.01$, respectively. The interaction of local proximity and SOA, and the three-way interaction of all factors were also not significant, $F(3, 99)=0.99$, $p=.390$, $\eta_p^2=.03$, and $F(3, 99)=0.43$, $p=.730$, $\eta_p^2=.01$, respectively.

Mean errors

Task 1. PEs varied between 2.2% and 4.6% per condition. In the corresponding ANOVA, no effect reached significance, all $F\text{s}\leqslant 2.35$, all $ps\geqslant .135$.

Task 2. The main effect of compatibility was significant, $F(1, 33)=42.76$, $p<.001$, $\eta_p^2=.56$, corresponding to more errors in the incompatible compared with the compatible condition (6.4% vs 3.5%). The main effect of hand distance was significant as well, $F(1, 33)=5.48$, $p=.025$, $\eta_p^2=.14$, corresponding to more errors in the local-proximal compared with the local-distal condition (5.6% vs 4.3%). The main effect of SOA was also marginally significant, $F(3, 99)=2.77$, $p=.052$, $\eta_p^2=.08$, with the largest number of errors at the shortest SOA (5.61%) and the lowest number at the longest SOA (4%). Interestingly, the two-way interaction of local proximity and compatibility was significant, $F(1, 33)=6.03$, $p=.020$, $\eta_p^2=.15$, reflecting a larger crosstalk effect in the proximal compared with the distal condition, namely 7.6% versus 3.6% in the near and 5.2% versus 3.4% in the far condition. The interaction of compatibility and SOA was also significant, $F(3, 99)=6.38$, $p=.001$, $\eta_p^2=.16$; the smallest crosstalk effect was observed at an SOA of 900 ms, and the largest crosstalk effect at an SOA of 300 ms, namely 4.0% versus 3.9% and 7.5% versus 3.1%, respectively. Neither the two-way interaction of local proximity and SOA nor the three-way interaction of all factors were significant, $F(3, 99)=0.46$, $p=.712$, $\eta_p^2=.01$, and $F(3, 99)=0.70$, $p=.556$, $\eta_p^2=.02$, respectively.

Discussion

This experiment investigated the influence of local stimulus-hand proximity on crosstalk effects in dual tasking. To this end, we varied the horizontal distance of the response hands from the centrally presented stimuli in a crosstalk paradigm. Contrary to our expectation, the compatibility effect in Task 1 (BCE) was neither reduced nor increased if the hands were near the stimuli compared with when they were far from the stimuli.

Importantly, however, for PEs, the compatibility effect in Task 2 (forward crosstalk) was significantly increased for the proximal compared with the distal condition, indicating that the conserved Task 1 shielding performance in the local-proximal condition came at the cost of a compensatory decline in Task 2 shielding. For example, Task 1 shielding might be more difficult in the local-proximal condition, as the overlapping attentional foci of the hands might lead to a higher risk of task confusion. Importantly, under the plausible assumption of a common cognitive resource underlying performance in both tasks (cf. Mittelstädt et al., 2022; Navon & Miller, 2002), Task 2 shielding may necessarily suffer when participants choose to conserve a high Task 1 shielding performance in the more demanding (i.e., local-proximal) condition.

Thus, while our hypotheses were originally directed at the BCE, the observed modulation of Task 2 crosstalk might essentially reflect the very same hypothesised process, namely an aggravation of task-shielding when the hands surround the stimuli in close local proximity. In fact, as Task 1 is clearly prioritised as the more important task by the experimental instructions, participants seemingly follow a viable strategy when a disturbance of Task 1 processing is forwarded to Task 2 processing rather than letting it affect Task 1 processing directly. Clearly, however, this post hoc interpretation is speculative and requires further investigation. First and foremost, a replication of the effect would be needed to determine whether the effect should be interpreted at all or should rather be regarded a Type 1 error.

In sum, then, our results so far suggest opposing influences of global and local stimulus-hand proximity on the quality of dual-tasking performance. While Experiment 1, in accordance with previous work (Fischer & Liepelt, 2020), has demonstrated that global stimulus-hand proximity supports a more separate processing of multiple stimuli in view, Experiment 2 suggests that participants have more difficulty separating the component tasks in a local-proximal as compared with a local-distal condition.

Nevertheless, at least two critical points weaken the certainty of this latter conclusion. First, Experiment 2 demonstrated only weak evidence of increased crosstalk in the proximal condition, as only the Task 2 compatibility effect (forward crosstalk) but not the Task 1 compatibility effect (BCE) was significantly altered. As stated above, a replication of such a reduced crosstalk effect for a locally proximal condition would render it much more meaningful. Second, our interpretation of the opposing influences of local and global stimulus-hand proximity rests on comparing the results of Experiment 1 and Experiment 2. More rigorous conclusions might be drawn when these opposing influences could be demonstrated within one experiment. To address these two critical points, a third experiment was carried out.

Experiment 3

In this third experiment, we tested the opposing influences of global and local stimulus-hand proximity, respectively, observed in Experiments 1 and 2, within one fully balanced within-subjects design. To this end, we designed a crosstalk experiment employing an orthogonal manipulation of these two proximity measures. Our hypotheses were as follows. First, we expected to observe a reduced BCE for the globally proximal as opposed to the globally distal condition, aiming to replicate our Experiment 1 and Fischer and Liepelt (2020). Statistically, this would become evident in a significant interaction of global proximity and compatibility in Task 1. Second, we expected to observe increased crosstalk for the locally proximal compared with the locally distal condition, aiming to replicate Experiment 2. Statistically, this would become evident in a significant interaction of local proximity and compatibility.

Methods

Participants. Thirty-two adult participants from the Hagen (Germany) area participated in the experiment. All participants reported normal or corrected-to-normal vision and provided written informed consent prior to data collection.

Stimuli and apparatus. The setup of this experiment extended the local proximity manipulation of Experiment 2 with the global proximity manipulation of Experiment 1 (see Figure 8). To this end, the same monitor setup as in Experiment 2 was used (see again Figure 5). In the global-proximal condition, the two pairs of custom-made response buttons were again placed directly on the screen with the palm of both hands facing downwards, one button placed to the left and one button placed to the right of the centre. In the global-distal condition, they were placed analogously on the wooden board located on the participants' legs. Importantly, for both the global-proximal and the global-distal conditions, the response buttons were positioned either 9 or 20 cm lateral to the centre of the screen/board, respectively, aiming to realise the local-proximal and the local-distal conditions within a single experiment. In all other regards, apparatus and stimuli were identical to Experiment 2.

Task and procedure. The instructions and a single trial were identical to Experiment 2. Again, all four S1 were combined equally often with all four S2, and these 16 combinations were repeated 4 times (one for each SOA), yielding

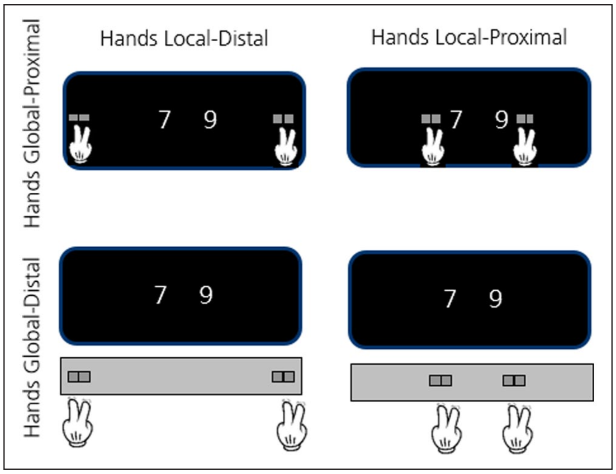

Figure 8. Schematic illustration of the orthogonal manipulation of local and global hand proximity employed in Experiment 3.

64 trials per block, presented in random order. One half of the experiment (e.g., Blocks 1–6) employed the global-proximal condition (i.e., hands on screen) while the other half (e.g., Blocks 7–12) employed the global-distal condition (i.e., hands in lap). Within each of the two global conditions, half of the blocks employed the local-proximal condition, and the other half employed the local-distal condition. The order of conditions was counterbalanced between participants. Hence, participants completed 12 blocks of 768 trials in total. At the beginning of each global × local proximity combination, participants completed a test block of 16 randomly drawn trials to become familiar with the task in the respective hand position. Participants were tested individually in one single session lasting about 80 min.

Statistical analysis. Data preparation and statistical analysis mirrored the analyses of Experiments 1 and 2. Mean RTs and PEs were analysed with a $2 \times 2 \times 2 \times 4$ repeated-measures ANOVA with the factors compatibility (compatible vs incompatible), local proximity (proximal vs distal), global proximity (proximal vs distal), and SOA (40, 130, 300, 900 ms). One participant with a very high error rate (>15%) was excluded from further analysis.

Results

The main results for this experiment are visualised in Figures 9 and 10. In addition, RTs and PEs as a function of SOA are given in Figure 11.

Mean RT

Task 1. The main effect of compatibility was significant $F(1, 30) = 19.67$, $p < .001$, $\eta_p^2 = .40$, reflecting faster responses in the compatible than in the incompatible condition, namely 850 ms versus 888 ms, respectively. The main effect of global proximity only approached significance, $F(1, 30) = 3.76$, $p = .062$, $\eta_p^2 = .11$, reflecting faster responses in the global proximal compared with the global distal condition (856 ms vs 882 ms, respectively). Contrary to expectation, the crosstalk did not meaningfully vary between the global-proximal (36 ms) and the global-distal condition (40 ms), $F(1, 30) = 0.08$, $p = .780$, $\eta_p^2 < .01$.

The crosstalk was numerically slightly increased for the local-proximal compared with the local-distal condition (42 ms vs 34 ms, respectively). Again, however, this difference was statistically not significant, $F(1, 30) = 0.24$, $p = .624$, $\eta_p^2 = .01$. As observed previously, the interaction of compatibility and SOA was significant, $F(3, 90) = 26.21$, $p < .001$, $\eta_p^2 = .47$, reflecting increasing crosstalk with shorter SOAs, namely 2 ms at the longest and 78 ms at the shortest SOA. From the remaining effects, none reached significance, all Fs $\leqslant 2.14$, all ps $\geqslant .124$.

Task 2. The main effect of compatibility was significant $F(1, 30) = 84.92$, $p < .001$, $\eta_p^2 = .74$, reflecting faster responses in the compatible than in the incompatible condition (867 ms vs 962 ms, respectively). The main effect of global proximity was significant as well, $F(1, 30) = 8.59$, $p = .006$, $\eta_p^2 = .22$, reflecting faster responses in the global-proximal condition (896 ms) compared with the global-distal condition (932 ms). Also, the main effect of SOA was significant, $F(3, 90) = 999.75$, $p < .001$, $\eta_p^2 = .97$, reflecting shorter RTs with longer SOAs (e.g., 1,115 ms at the shortest SOA and 630 ms at the longest SOA) and thus a PRP effect. As expected, the crosstalk was numerically reduced for the global-proximal as compared with the global-distal condition, namely 89 ms versus 101 ms. Statistically, however, this difference was not reliable, $F(1, 30) = 1.52$, $p = .227$, $\eta_p^2 = .05$.

As expected, the crosstalk was numerically increased for the local-proximal compared with the local-distal condition (100 ms vs 89 ms, respectively). Again, however, this difference was statistically not significant, $F(1, 30) = 0.86$, $p = .362$, $\eta_p^2 = .03$. The interaction of SOA and compatibility was significant, $F(3, 90) = 34.81$, $p < .001$, $\eta_p^2 = .54$, reflecting a smaller crosstalk effect with longer SOAs (45 ms at the longest SOA and 145 ms at the shortest SOA). From the remaining effects, none reached significance, all Fs $\leqslant 2.62$, all ps $\geqslant .072$.

Mean errors

Task 1. The main effect of global proximity was significant, reflecting less errors in the global-proximal compared with the global-distal condition (1.6% vs 2.3%, respectively), $F(1, 30) = 8.00$, $p = .008$, $\eta_p^2 = .21$. Contrary to our expectation, the interaction of compatibility and global proximity and the interaction of compatibility and local proximity were not significant, $F(1, 30) = 0.34$, $p = .563$, $\eta_p^2 = .01$, and $F(1, 30) = 0.40$, $p = .531$, $\eta_p^2 = .01$,

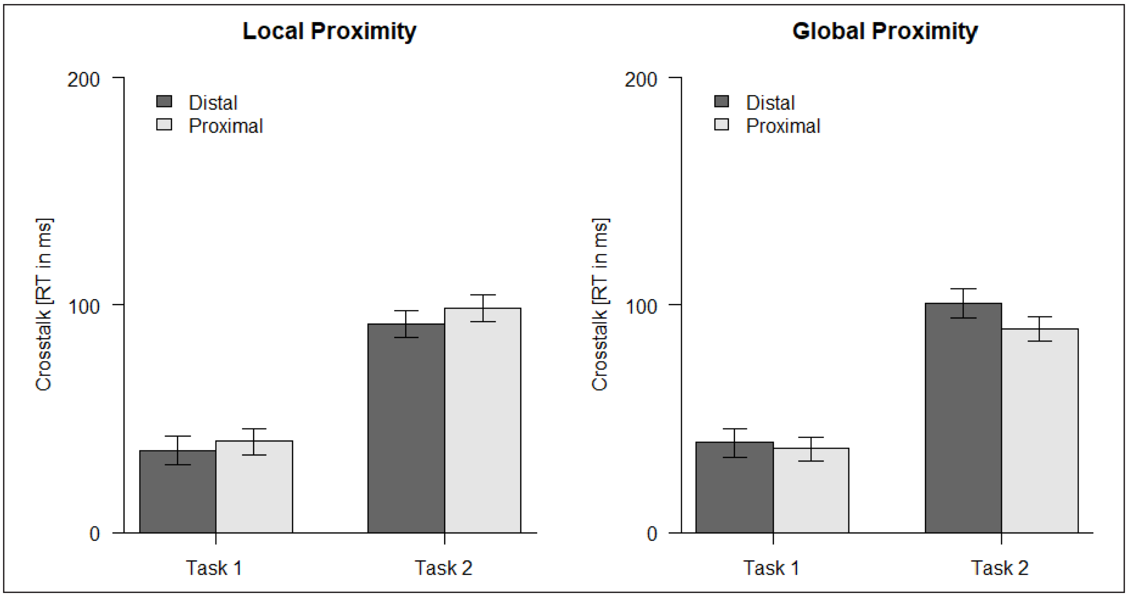

Figure 9. Experiment 3: Task 1 and Task 2 crosstalk effects in the RTs for local proximity (left panel) and global proximity (right panel).

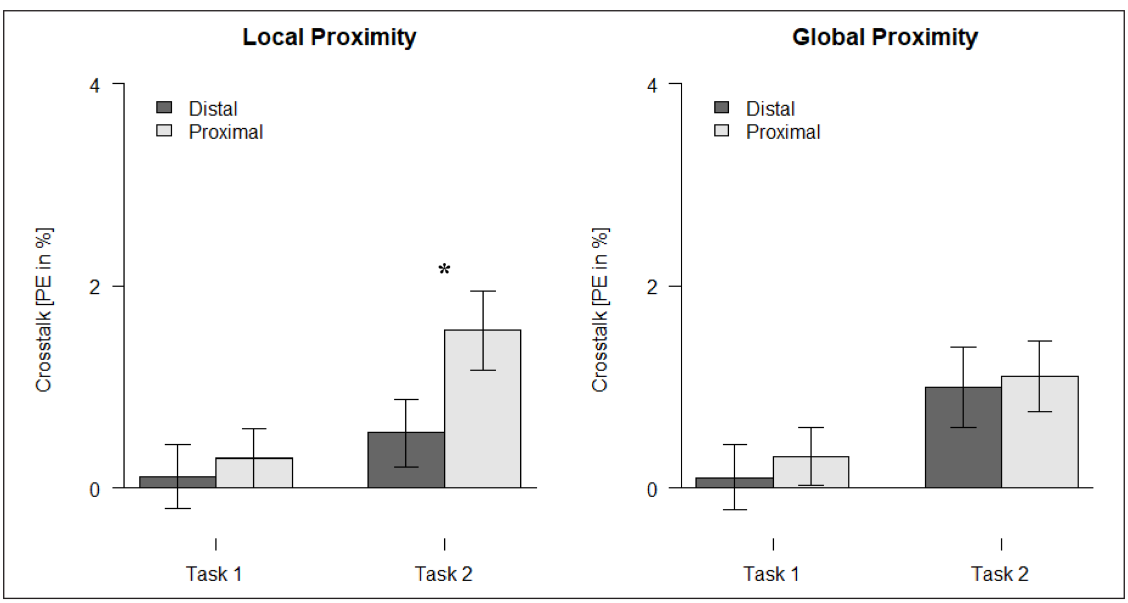

Figure 10. Experiment 3: Task 1 and Task 2 crosstalk effects in the PEs for local proximity (left panel) and global proximity (right panel). *p < .05.

respectively. Numerically, the PEs in these conditions varied only marginally between 1.5% and 2.3%. None of the remaining effects reached significance, all Fs $\leqslant 2.73$, all ps $\geqslant .062$.

Task 2. The main effect of global proximity was significant, $F(1, 30) = 8.22$, $p = .008$, $\eta_p^2 = .22$, reflecting less errors in the global-proximal (2.8%) compared with the global-distal (3.7%) condition. Furthermore, the main effect of compatibility was significant, $F(1, 30) = 12.26$, $p = .001$, $\eta_p^2 = .29$, reflecting less errors in the compatible than in the incompatible condition, namely 2.7% versus 3.8%. Most importantly, the interaction of local proximity and compatibility was significant, $F(1, 30) = 4.70$, $p = .038$, $\eta_p^2 = .14$, reflecting increased crosstalk in the local-proximal compared with the local-distal condition. Specifically, in the proximal condition, PEs were 4.1% (incompatible) versus 2.5% (compatible), while in the distal condition, they were 3.5% (incompatible) versus 3.0% (compatible). This interaction of compatibility and local proximity

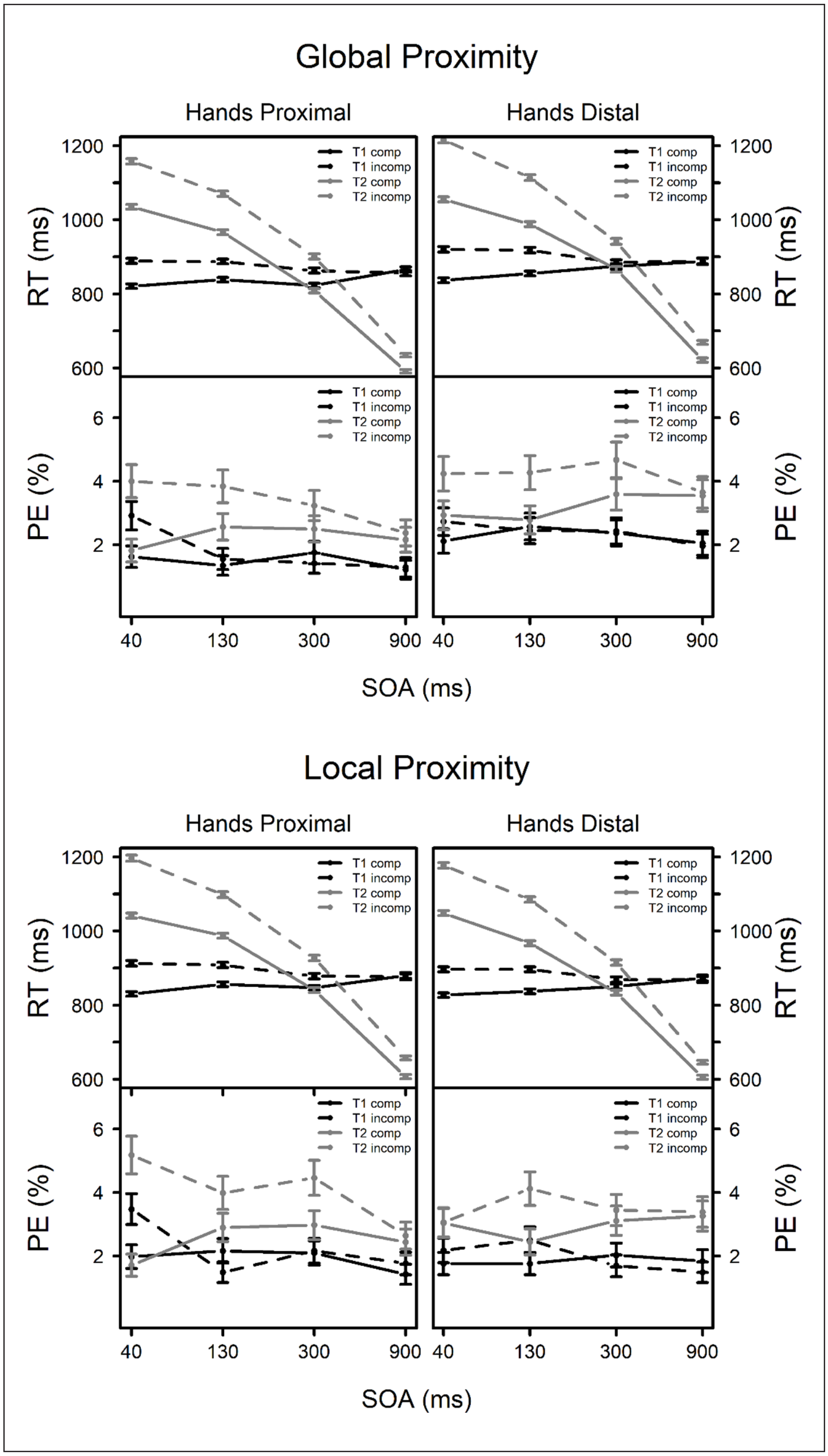

Figure 11. Experiment 3: RT and PE as a function of SOA, compatibility, Task, global proximity (upper panel), and local proximity (lower panel).

was further modulated by SOA, $F(3, 90)=4.15$, $p=.008$, $\eta_p^2=.12$, reflecting a stronger crosstalk increment by proximity at shorter SOAs compared with longer SOAs. That is, at the shortest SOA, the crosstalk was substantially larger for the local-proximal condition (5.2% vs 1.7%) than for the local-distal condition (3.1% vs 3.0%), while at the longest SOA, the crosstalk was not meaningfully different for the local-proximal condition (2.6% vs 2.4%)

compared with the local-distal condition (3.4% vs 3.3%). From the remaining effects, none reached significance, all $Fs \leq 2.33$, all $ps \geq .079$.

Discussion

This experiment tested for opposing effects of local and global stimulus-hand proximity on interference effects in dual-tasking in a single experiment. To this end, these two factors were varied orthogonally in a crosstalk experiment. We expected to observe a reduced BCE in the global-proximal compared with the global-distal condition. On the contrary, we expected to observe an increased forward crosstalk effect for local-proximal compared with the local-distal condition.

Unexpectedly, the BCE was not meaningfully modulated by global proximity. Thus, contrary to Experiment 1 and previous work (Fischer & Liepelt, 2020), this experiment does not support the claim that global stimulus-hand proximity influences the quality of dual-tasking performance in the current experimental setup. This null effect might either reflect a Type 2 error or be the result of small differences in the experimental setup between the present experiment and previous studies (see General Discussion for a thorough discussion of these points).

As expected, the forward crosstalk effect was significantly increased for the locally proximal compared with the locally distal condition. That is, for Task 2, the compatibility effect as reflected in PEs was significantly larger for the local-proximal condition than for the local-distal condition. This finding represents a replication of the main finding of Experiment 2. Again, this result suggests that participants have more difficulty shielding the two component processes from each other in the local-proximal condition. Here, participants are seemingly able to conserve Task 1 shielding performance only at the expense of a compensatory decrement in Task 2 shielding performance.

General discussion

The present study aimed at advancing the understanding of how the spatial proximity of hands and stimuli can influence human dual-tasking performance. A first goal was to investigate whether the observed crosstalk reduction for a global-proximal compared with a global-distal condition (e.g., Fischer & Liepelt, 2020) is caused by global stimulus-hand proximity or rather stimulus-effect proximity. To this end, in Experiment 1, both factors were varied orthogonally in a standard crosstalk experiment. Crucially, global hand proximity, but not effect proximity, caused a reduction of between-task interference: the BCE was smaller when the response buttons were placed directly at the screen (global-proximal condition) compared with when they were placed far from the screen (global-distal condition), but the BCE did not differ between the effects-proximal and the effects-distal condition.

Hence, although the anticipation and monitoring of action effects plays a substantial role in dual-tasking (e.g., Janczyk & Kunde, 2020; Wirth et al., 2018), the results of Experiment 1 do not provide evidence that these effect-based processes are also involved in mediating the influence of stimulus-hand proximity on dual-tasking performance. Rather, these results are consistent with Fischer and Liepelt (2020) arguing that hand-specific processing benefits can facilitate the separation of two concurrently processed tasks. For example, when the hands are placed directly near the task-specific stimuli, the dimensional (spatial) overlap between a stimulus and its assigned response-effector might lead to a stronger coupling of sensory codes with their associated motor patterns (Hommel et al., 2001). Accordingly, the risk of task confusion (i.e., mistakenly binding a stimulus feature from one component task into the response selection process of the other component task) might be reduced (cf. "the dual-task binding problem," Koch, 2009; Logan & Gordon, 2001).

Note that under this interpretation, the improved task-shielding near the hands as observed in the present and earlier studies emerges as a by-product of the enhanced perception-action coupling near each hand. On the contrary, previous accounts of task shielding have put more emphasis on cognitive control demands (Fischer & Hommel, 2012; Logan & Gordon, 2001). Thus, given that some studies indicate higher cognitive control engagement for stimuli presented near the hands (e.g., Abrams & Weidler, 2014, but see Wang et al., 2014, 2021), it is also conceivable that a general cognitive control enhancement in the global-proximal condition might have enabled participants to shield the component tasks more effectively from each other than in the global-distal condition. In any case, it is of course possible that stimulus-hand proximity affects both visuomotor and cognitive factors, and both types of factors might potentially influence task-shielding performance (cf. Logan & Gordon, 2001). Future research might be addressed at disentangling these relations in more detail.

A second goal of the present study was to investigate the spatial constitution of the presumed hand-specific processing enhancements. For example, in Experiment 2, we investigated whether the physical variation of stimulus-hand proximity (i.e., different levels of local proximity) can cause an alteration of dual-tasking performance when the hands are kept constantly in a shared attentional window with the stimuli (i.e., realising constant global proximity). We reasoned that moving the hands horizontally closer to the centrally presented stimuli at the screen might hamper the correct assignment of stimuli and responses, which should become evident in increased between-task interference. Importantly, while the BCE was not modulated by local proximity, we observed a compensatory reaction in Task 2. That is, the forward crosstalk was significantly increased for the local-proximal as opposed to the local-distal condition.

Although this result was unexpected in Experiment 2, its replication in Experiment 3 renders it unlikely to be an incidental observation. Rather, taken together, Experiments 2 and 3 do provide new evidence for the hypothesis that task-shielding becomes more difficult in the local-proximal as opposed to the local-distal condition. Specifically, the observed compensatory effect in Task 2 indicates that participants could indeed conserve the task-shielding performance in Task 1, however only at the expense of a performance decrement in Task 2.

Note that this latter interpretation is consistent with theoretical approaches that conceptualise task-shielding performance in terms of a strategic adjustment of top-down attentional control factors. For example, according to the Executive Control Theory of Visual Attention (ECTVA; Logan & Gordon, 2001), humans—when faced with interference from multiple task requirements—effortfully adjust control parameters in a way that selectively enhances (weakens) the prioritised (non-prioritised) task to support task-shielding (cf. Koch et al., 2010). Thus, regarding the compensatory effects observed for the local-proximal condition in Experiments 2 and 3, participants might make the strategic choice to protect Task 1 from interference, as Task 1 is clearly prioritised by the task instructions. As a result, due to the additional processing presumably required to correctly assign stimuli and responses in the local proximal condition, shielding of Task 1 might necessarily come at the cost of a performance decrement in Task 2 shielding.

In sum, then, a picture arises in which global and local stimulus-hand proximity exert opposing influences on the quality of dual-tasking performance. Experiment 1—in accordance with previous work (Fischer & Liepelt, 2020)—suggests that placing the response hands near their respective task-specific stimuli (hence establishing global stimulus-hand proximity) supports a more separate processing of the two component tasks. On the other hand, Experiments 2 and 3 suggest that participants have more difficulty separating the two component tasks when the hands are moved horizontally closer to centrally presented stimuli (hence increasing local proximity). Taken together, the results are consistent with the view that peri-hand spaces can be conceptualised as hand-specific action-related fields which are graded with proximity (Bufacchi & Iannetti, 2018). Most importantly, regarding multitasking, these hand-specific processing benefits can apparently facilitate or hamper task-shielding, depending on the specific arrangement of hands and stimuli.

Noteworthy, however, in contrast to this viewpoint, we did not observe a modulation of the amount of crosstalk by global stimulus-hand proximity in Experiment 3. This result is surprising, as Experiment 1 and previous studies (Fischer & Liepelt, 2020) have demonstrated a reliable reduction of the BCE in a global-proximal compared with a local-distal condition. One potential reason for the divergence of this experiment's results from previous studies might be small differences regarding the experimental procedure that were required to integrate global and local proximity manipulations within a single experimental setup. For example, in the present study, participants placed their hands on the screen with the palms facing downwards in the global-proximal condition, while the global-proximal condition of Experiment 1 in Fischer and Liepelt (2020) required participants to place their hands at the side of the screen with the palms facing inwards to the stimuli. In fact, there is some evidence indicating that the orientation and position of the hand's functional surface can affect the quality of visual processing of nearby stimuli (Davoli & Brockmole, 2012; Reed et al., 2010), analogously to how subtle changes in grasp posture (Thomas, 2015), anatomical location (Tseng & Bridgeman, 2011), or handedness (Le Bigot & Grosjean, 2012) can modulate the outcome of stimulus-hand proximity experiments. In addition, the tilted monitor setup in Experiment 2 differs from Experiment 1 and previous studies (Fischer & Liepelt, 2020) using a standard CRT monitor. This may have also affected participants' body posture, thus potentially contributing to the global hand proximity effect. In any case, the present study's disparate results concerning global hand proximity are well in line with the observation that near-hand effects might be relatively fragile and susceptible to minor procedural changes in general. For example, Andringa et al. (2018) could not replicate some of the classic findings of the field, neither when a modified hand-device nor the original setup was used. However, as some of these findings have been replicated elsewhere (Agauas et al., 2020), it appears that some nuanced and not yet sufficiently understood factors related to the experimental setup can influence hand-nearness effects. In the light of these considerations, the seemingly disparate results of Experiment 1 and Experiment 3 potentially add to a growing body of research helpful for identifying such subtle modulators.[1]

In sum, the present study supports the notion that hand-specific attentional processing benefits strengthen perception-action coupling near each hand. Importantly, in task setups where multiple stimuli are assigned to multiple responses, stimulus-hand proximity can either facilitate or hamper control of crosstalk interference, depending on the exact arrangement of hands and stimuli. As a conclusion for the field of research investigating hand-nearness effects, it thus needs to be considered that different stimulus-hand proximity measures can have different effects, depending on the particular task at hand.

Compliance with ethical standards

All procedures performed in studies involving human participants were in accordance with the ethical institutional standards and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards. Informed consent was obtained from all individual participants included in the study.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Note

1. An alternative potential explanation for the present null finding is that it constitutes a Type 2 error. In fact, the failure to observe a significant effect in a series of replications is counterintuitively likely (see, for example, Francis, 2012). For example, consider a true effect that is being investigated with a series of three experiments. Consider further that each of these experiments has a power of 80%. The probability of observing the effect in all three experiments is $0.8 \times 0.8 \times 0.8 = 0.512$. Accordingly, the probability of observing at least one non-significant result will be $1 - 0.521 = 0.488$. Thus, the probability of three successful replications is about the same as the probability of the occurrence of a Type 2 error within this hypothetical series.

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