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Unravelling intention: Distal intentions increase the subjective sense of agency

Mikkel C. Vinding [a,*], Michael N. Pedersen [a], Morten Overgaard [a,b]

[a] CNRU, CFIN/MindLab, Aarhus University, Denmark
[b] CNRU, Dept. of Communication and Psychology, Aalborg University, Denmark

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ABSTRACT

Experimental studies investigating the contribution of conscious intention to the generation of a sense of agency for one's own actions tend to rely upon a narrow definition of intention. Often it is operationalized as the conscious sensation of wanting to move right before movement. Existing results and discussion are therefore missing crucial aspects of intentions, namely intention as the conscious sensation of wanting to move in advance of the movement. In the present experiment we used an intentional binding paradigm, in which we distinguished between immediate (proximal) intention, as usually investigated, and longer standing (distal) intention. The results showed that the binding effect was significantly enhanced for distal intentions compared to proximal intentions, indicating that the former leads to stronger sense of agency. Our finding provides empirical support for a crucial distinction between at least two types of intention when addressing the efficacy of conscious intentions.

1. Introduction

The sense of agency (SoA) is the on-going subjective experience of being in control of our own actions. The SoA is typically explained in terms of a predictive coding model utilising comparison between the predicted and actual sensory feedback resulting from an action (Blakemore, Wolpert, & Frith, 2000; Wolpert & Flanagan, 2001). On this account, voluntary actions generate efferent motor commands, which in addition to causing the intended bodily action generate an "efference copy" signal, utilised in the construction of a forward model predicting the sensory consequences of that performed action. When there is correspondence between the internal model and actual sensory feedback signals, the SoA is maintained.

The observation that the SoA depends upon consistency between the internal model and action outcome has been used to experimentally generate a "false" SoA: subjects will experience themselves as the author of an outcome despite having no actual influence over the event, as long as there is a spatial–temporal correspondence between the intention and the outcome (Engbert & Wohlschläger, 2007; Engbert, Wohlschläger, & Haggard, 2008; Kühn & Brass, 2009; Moore, Wegner, & Haggard, 2009; Wegner & Wheatley, 1999). Such findings have been used to challenge the common-sense notion of free will; that is assuming conscious intention is the causal origin of actions (Wegner, 2002), and has led some researchers to conclude that the experience of intention is mainly a post hoc retrospective inference based on the observed effects of one's own movements (Banks & Isham, 2009; Wegner & Wheatley, 1999).

Experimental studies investigating voluntary action often conceptualise intention as the experience of wanting to perform an action immediately before this action. This is however only a small part of what the concept of intention denotes,

* Corresponding author. Address: Nørrebrogade 44, Building 10G, 4th Floor, 8000 Aarhus C, Denmark.
E-mail address: Mikkel@cnru.dk (M.C. Vinding).

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and we can theoretically distinguish between different kinds of intention with respect to various factors such as temporal features, content, consistency or context (Brass & Haggard, 2008; Pacherie, 2008; Pacherie & Haggard, 2010). When considering the causal efficacy of intention, we need to take these different meanings of intention into account. First, in order to test whether the theoretical distinctions can be empirical verified and then in order to investigate whether different kind of intentions have different functional roles in action generation and in relation to SoA. In the present study we address this issue by distinguishing between *proximal* intentions related to the immediate execution of action, and *distal* intentions, i.e. intentions about actions to be performed at a later point in time (Mele, 2010; Pacherie, 2008; Searle, 1980). Using this terminology, we see that most experimental investigations of intentions and SoA investigate only proximal intentions neglecting the longer-duration distal intentions.

A common quantitative measure of SoA is the intentional binding paradigm (Moore & Obhi, 2012). Intentional binding refers to conditions in which an action, usually a finger movement or a keypress, is followed by an auditory tone. When the action is voluntary, the perceived interval between the two events is shortened, compared to non-voluntary actions (Haggard & Clark, 2003; Haggard, Clark, & Kalogeras, 2002). The perceived time of the press is shifted forward in time toward the tone and the perceived time of the tone is shifted backwards toward the press. The assumption is that the closer the press and tone is perceived the stronger is the SoA.

The aim of the present experiment is to investigate whether difference between when the intention to act is either proximal or distal entails differences in SoA, using an intentional binding paradigm. How SoA is affected when it is the intention that is moved backwards and the action kept constant have, to our knowledge, not been tested before.

2. Material and methods

2.1. Participants

Eighteen healthy participants (11 females) volunteered to participate in the experiment. Their age ranged from 21 to 35 years (mean-age = 24.1 years). All participants gave their written consent before participating and received payment of 150 DKK for participating. The experiment took approximately 1.5 h. The experiment was conducted in accordance with the Declaration of Helsinki and approved by the local ethics committee.

2.2. Experimental design

The experiment utilised an intentional binding paradigm (Haggard et al., 2002; Moore & Obhi, 2012), in which participants face a Libet-style clock face (Libet, Wright, & Gleason, 1982), which they use to time and report events and awareness of action. Participants had to press a key at random times in a self-paced manner. When the key was pressed, a tone would be presented after a 250 ms delay. The clock continued running in a random interval of 600–1000 ms after the last event, and then stop. Afterwards the participants had to report the position of the clock, by directing the clock to the same location where they perceived the tone or the press, depending on the instruction.

While the clock was running, letters were shown in the centre of the clock. The letters consisted of 17 consonants shown one at a time with duration of 500 ms per letter, in a pseudo-random order, which ensured one particular letter would reappear within a range of 3–8 letters (1.5–4 s).

2.3. Procedure

The experiment had seven different conditions, divided into two types of target conditions; proximal intentional conditions and distal intentional conditions, where actions are followed by a tone (see Fig. 1), and three baseline conditions where only action or a tone occurs (see Table 1). The order of conditions was randomized. The conditions ran in blocks consisting of 40 repetitions. Each block was preceded by five training trials to accustom participants to the specific instructions for the upcoming block. Participants were instructed to fix their gaze at the letters in the middle of the clock during all conditions.

2.3.1. Proximal intention condition

Proximal intention conditions were similar to previous experiments using intentional binding (see Moore & Obhi, 2012). Participants monitored the clock and pressed the button as soon as they felt the intention to do so. Each keypress was followed by an auditory tone after 250 ms. After each trial participants had to report either the experienced time of the press or the tone. During the task participant were instructed to monitor the letters in the middle of the clock as well, even though they did not use the letters in this condition.

2.3.2. Distal intention condition

In the distal intention conditions subjects were required to monitor the clock and form an intention (similar to the proximal intention condition), but instead of pressing the button as soon as they have the intention, they only had to notice the letter in the middle of the clock, then wait until the same letter appeared again, and then press the key. In this manner the delay between when an intention is formed and the execution of the action always fell within a range of 1.5–4 s. The press

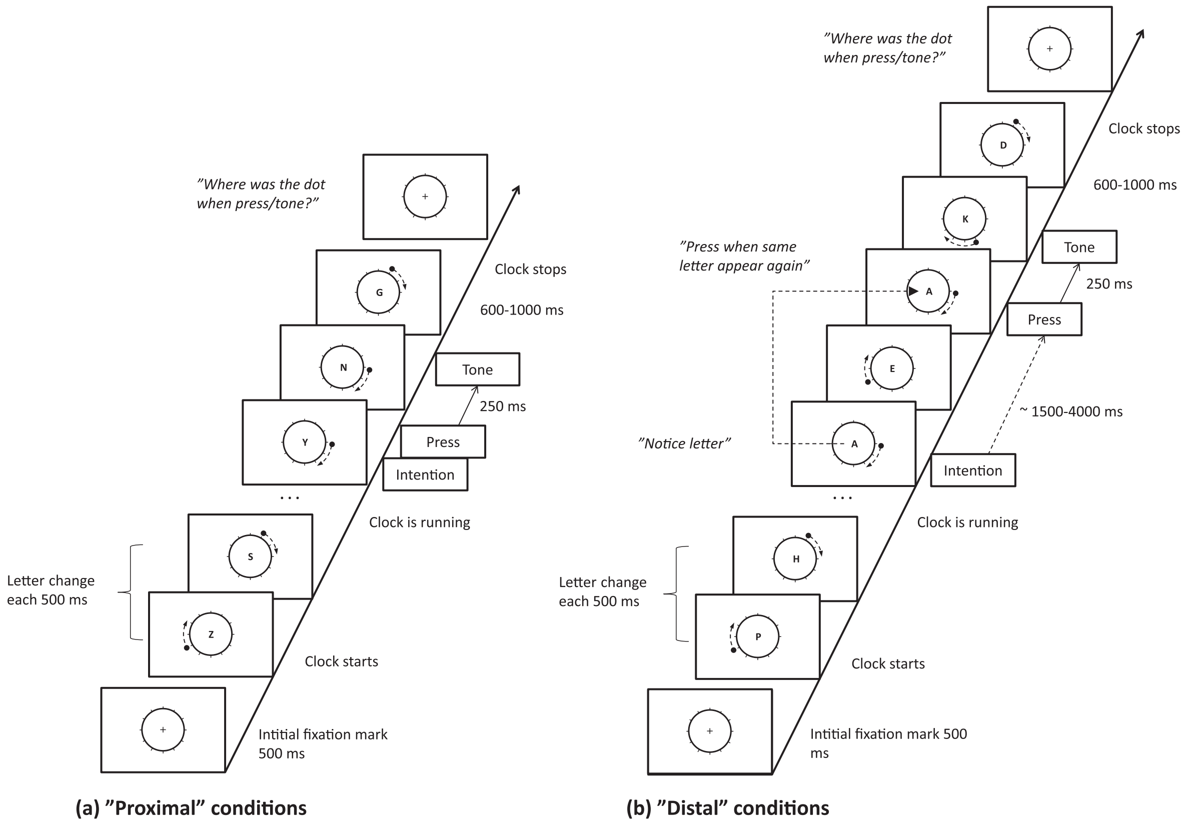

Fig. 1. Trial procedure for target conditions in the experiment. In both condition each trial starts with a fixation screen is presented for 500 ms. Then the clock starts running with letters changing each 500 ms. This constitutes until participants press the key, upon which a tone is played 250 ms later. In the proximal condition (a) participants press the key as soon as they experience the intention to act. In the distal condition (b) notice the present letter, when they experience the intention to act, and then press the key when the letter reappears. In both conditions participants then have to answer the position of the clock at the time of either press or tone.

Table 1
Summary of conditions in the experiment: Two target conditions where intention were proximal, two target conditions where intention were distal, and three baseline conditions. The right column indicates what subject had to report – either experienced time of press or time they heard the tone.

Proximal intention conditions:	
Wait → Intention → Press → Tone	Report time of Tone
Wait → Intention → Press → Tone	Report time of Press
Distal intention conditions:	
Wait → Intention → wait → Press → Tone	Report time of Tone
Wait → Intention → wait → Press → Tone	Report time of Press
Baseline (*single event*) *conditions*:	
Wait → Tone	Report time of Tone
Wait → Intention → Press	Report time of Press
Wait → Intention → wait → Press	Report time of Press

was followed by a tone after 250 ms as before. After each trial participants had to report the position of the clock, either when they pressed the key or when they heard the tone.

2.3.3. Baseline conditions

The experiment had three baseline conditions; one for tone and two for press. This follows the conventional method baseline conditions are used in studies using the intentional binding paradigm, where the baseline is similar to the target conditions, but where only one of the events (press/tone) occurs (Haggard et al., 2002; Moore & Obhi, 2012). In the tone-baseline conditions, the tone would be played at a random time, while participants watched the clock and letters. Participants then had to report the time they experienced the tone. The two single event press conditions differed in respect to whether the intention to perform the press was proximal or distal, and the instructions were similar to the target conditions, but without a tone being played after the key-press. Participants then reported the time they experienced the press.

2.4. Data analysis

Perceptual shifts were calculated similar to previous intentional binding studies (Haggard et al., 2002; Moore & Obhi, 2012). The reported times were compared to the actual location of the event, logged by the stimulus computer, to give the judgement error of the subjective times for each trial. The perceptual shift was calculated by subtracting the mean judgement error of the baseline conditions from the target conditions. For tone conditions, the baseline tone condition was subtracted from both the distal- and proximal tone condition. This gave four modes for each participant; perceptual shift for action and for tone when intention is distal, and perceptual shift for action and for tone when intention is proximal. Data was entered into a 2×2 way repeated measures ANOVA with intention type (proximal/distal) as the first factor and report type (tone/press) as the second factor.

As the letters were set to repeat at random with a 3–8 letter interval, the effect of distal intention could be confined to the trials in which the delay between intention and action is shortest. To test whether the delay between intention and execution of action in the distal intention conditions (including the distal-control condition) had any effect on binding, an ANCOVA was performed on the error-times per trial with distal condition type (tone/press/single) as within factor and delay between letters as the covariant factor. If the effect of distal intention on SoA judgements depends upon the delay between intention and action, a correlation between the letter interval and error-time would be expected.

3. Results

As expected, we found a binding effect similar to previous intentional binding experiments, where a negative shift was observed for tone conditions and a positive shift for the press conditions (see Fig. 2). This prediction was confirmed by fact that the 2×2 way repeated measure ANOVA showed a main effect of report type, $F(1,17) = 17.4$, $p < .001$, $\eta^2 = .26$. The 2×2 way repeated measure ANOVA revealed a significant main effect of intention type, $F(1,17) = 8.77$, $p = .008$, $\eta^2 = .065$. Whether the intention was distal or proximal did influence the binding effect. The interaction between report type and intention type was not significant, $F(1,17) = 1.63$, $p = .22$, $\eta^2 = .017$.

The perceptual shift of tone was much larger when intention was distal ($M = -150.59$ ms, SD = 166.4 ms), than when intention was proximal ($M = -63.2$ ms, SD = 102.5 ms). The perceptual shift of press was however larger for the proximal condition ($M = 39.4$ ms, SD = 51.4 ms) than for the distal condition ($M = 10.1$ ms, SD = 103.5 ms). Post hoc comparison between each condition showed significant difference between all conditions ($p < .05$, Holm–Bonferroni corrected) except for the difference between press for distal- and proximal conditions ($p = .31$, Holm–Bonferroni corrected).

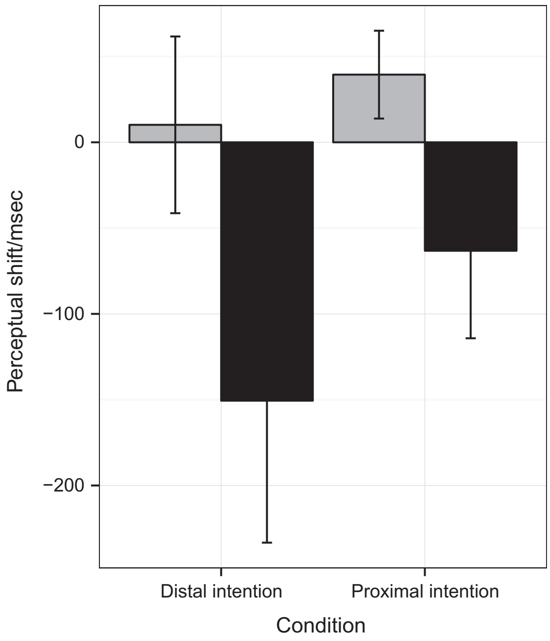

Fig. 2. Mean perceptual shift (in ms) of perceived time of press (grey) and perceived time of tone (black) depending on whether the intention to act were distal and proximal. Distal intention conditions showed stronger perceptual shift of tone than proximal intention conditions, whereas the difference between the perceptual shifts of press did not differ significantly. Error-bars indicate 95% CI of the means.

The analysis of covariance found only a significant effect of condition type $F(2,278) = 9.10$, $p < .001$, $\eta_p^2 = .062$. There were no effect of the time between letters as covariate $F(1,278) = 0.37$, $p = .38$, $\eta_p^2 = .0028$. This indicates that the effect of distal intention is not bound to a specific delay between intention and action.

4. Discussion

The present study shows that distal intention leads to a stronger binding effect than proximal intention under the conditions of this experimental paradigm. As usually interpreted, this means that distal intention formation induce stronger SoA for the performed action, than proximal intention. When the intention to act is formed in advance, it entails a stronger SoA than when the intention is immediately followed by the action.

Previously, it has been suggested that proximal intention could be present 1.5 s before action, but only measured much later, due to bias in timing methods (Matsuhashi & Hallett, 2008). Therefore, it seems natural to consider whether the effect of distal intention was, in fact a particularly ''early'' proximal intention, making the theoretical distinction between proximal and distal intentions invalid. We argue that this is not the case for several reasons. First, our data shows a stronger binding effect for distal intention, where no effect would be expected if it were the same process. Second, if this were the case, it would have predicted a weaker binding effect as the delay between intention and action increased. This is not what we found in the present experiment. Distal intention does appear to be a separate process and influence SoA differently than proximal intention.

Since distal intentions are formed well before the actual action, they necessarily involve an additional cognitive load in order for the intention to be maintained in working memory. In the present experiment participants had to keep a letter in their working memory until it reappeared in the distal condition but not in the proximal condition. Since cognitive and attentional load is known to affect temporal judgements (Block, Hancock, & Zakay, 2010; Brown, 1997), the difference in binding effect between proximal and distal intention might be a confound of the additional working load in the distal condition, even if it is only a small additional load. A recent study has specifically investigated the effect of working memory load on agency ratings by having participants remember strings of letters and recalling them after having performed a simple finger movements (Hon, Poh, & Soon, 2013). This showed that working memory load only had little effect over agency ratings -and the effect it had was a decreased agency rating. Given this result it would be expected that additional working memory load would lead to less total binding effect for the distal condition. However, in the present study, the opposite was the case. If working memory load indeed decreases sense of agency, then it must be concluded that whatever information that is present in distal intentions must be that must greater in accommodating the effect of working memory load.

Divided attention between the clock and the letters is another possible confound. While the task certainly entails some kind dual task, we do not believe this explain the result. First, the participants were instructed to monitor the letters during all conditions, even in the conditions where they did not use them to time their intention. Second, in the conventional way the clock is used, participants are told not to follow the clock with their gaze, but passively monitor the clock and focus on a fixation mark in the centre (Libet et al., 1982). This instruction was also used in the present experiment, only the letters replaced the fixation mark in the middle of the clock. Finally, the binding paradigm has previously been used along other visual stimuli (Desantis, Roussel, & Waszak, 2011; Engbert & Wohlschläger, 2007) even used along more complex tasks, for example moral choice tasks (Moretto, Walsh, & Haggard, 2011). The results from these studies are in concordance with what would be expected, compared to studies using only the clock. A study investigating time perception of simulations events using intentional binding (Wenke & Haggard, 2009), concluded that dual attention could not explain changes in the binding effect. Rather the binding effect was proposed to be caused by a global modulation of time perception, affecting all perceived events within a limited time-window, when performing voluntary actions.

The results of the present study are in concordance with the forward model comparison between the predicted and actual sensory feedback, but does not support the position that the experience of conscious intention in general is a post hoc inference based on outcome (e.g. Wegner & Wheatley, 1999). This could be the case for proximal intention, on which experimental investigation of intention has been focused, but does not consistent with distal intentions. First, because the distal intention is consciously experienced before any post-action feedback is present. Second, the stronger binding effect for distal intention indicates that distal intention does seem to contain additional information that is integrated in the process generating SoA. So while some type of intention seems to be causally irrelevant (Banks & Isham, 2009; Wegner, 2002), others seem to actually play a distinct causal role in action and SoA.

One remaining question is how distal intentions differ from proximal intentions when integrated into the processes underlying SoA. One interpretation is that distal intention increases the outcome prediction of the action. Outcome prediction of pending actions have been shown to be fundamental in intentional binding (Desantis et al., 2011; Engbert & Wohlschläger, 2007; Moore & Haggard, 2008; Moore, Lagnado, Deal, & Haggard, 2009), and SoA in general (Aarts, Custers, & Wegner, 2005; Wegner & Wheatley, 1999), as well as the cornerstone of Bayesian modelling of motor feedback (e.g. Knill & Pouget, 2004; Körding & Wolpert, 2004; Stevenson, Fernandes, Vilares, Wei, & Körding, 2009). When forming intention in advance of the action, the temporal delay might provide a stronger outcome prediction than immediate action, thereby enhancing SoA. There would be time for neural simulation of the forthcoming action, adjusting the prior, or better computation of optimal state estimation (Scott, 2012; Todorov & Jordan, 2002). No matter if the effect of distal intention is interpreted as stronger outcome prediction or distinct information, it is clear the distal intention has a significant effect on the mechanisms underlying SoA.

In conclusion, we have demonstrated that the temporal feature of intention impact the resulting SoA. Understanding the mechanisms connecting distal intentions and SoA is an important step for future research. Here, we provide evidence that distal intentions can increase SoA, a crucial finding in a field where intention is more or less synonymous with proximal intention. We believe that the here presented empirical support for a distinction between – at least – two types of intention must be taken into account in future experiments on intention, and it suggests a need for future studies to further disentangle components in the conglomerate concept of intention.

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