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The self-consistency effect seen on the dot perspective task is a product of domain-general attention cueing, not automatic perspective taking

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Abstract

It has been proposed that humans automatically compute the visual perspective of others. Evidence for this view comes from the Dot Perspective Task. In this task, participants view a room in which a human actor is depicted, looking either leftwards or rightwards. Dots can appear on either the left wall of the room, the right wall, or both. At the start of each trial, participants are shown a number. Their speeded task is to decide whether the number of dots visible matches the number shown. On consistent trials the participant and the actor can see the same number of dots. On inconsistent trials, the participant and the actor can see a different number of dots. Participants respond faster on consistent trials than on inconsistent trials. This self-consistency effect is cited as evidence that participants compute the visual perspective of others automatically, even when it impedes their task performance. According to a rival interpretation, however, this effect is a product of attention cueing: slower responding on inconsistent trials simply reflects the fact that participants' attention is directed away from some or all of the to-be-counted dots. The present study sought to test these rival accounts. We find that desk fans, a class of inanimate object known to cue attention, also produce the self-consistency effect. Moreover, people who are more susceptible to the effect induced by fans tend to be more susceptible to the effect induced by human actors. These findings suggest that the self-consistency effect is a product of attention cueing.

Keywords:

Dot Perspective Task; Attention cueing; Visual perspective taking; Submentalizing

1. Introduction

Humans have an unparalleled ability to reason about the mental states of others, for example to reflect upon their intentions, desires and beliefs (Tomasello, 2018; Wimmer & Perner, 1983). One aspect of this ‘theory of mind’ is the capacity to compute the visual perspective of others - what they can and cannot see (Todd & Simpson, 2017). Visual perspective taking is thought to be crucial in both collaborative and competitive situations. It typically emerges by 24 months of age and may scaffold the emergence of more sophisticated forms of mental state reasoning later in development (Batki, Baron-Cohen, Wheelwright, Connellan, & Ahluwalia, 2000; Frith & Frith, 2003; Moll & Tomasello, 2006). So-called level 1 perspective taking refers to the ability to infer whether another person can see an object or not; i.e., if the person’s eyes are open and is their line of sight unobstructed? In contrast, level 2 perspective taking refers to the ability to infer how a scene appears to someone with a different point of view.

It has been proposed that human adults automatically compute the visual perspective of others (Apperly & Butterfill, 2009). Visual perspective taking can be considered automatic to the extent that it is difficult, or perhaps even impossible, to inhibit. It has been suggested that the putative capacity to compute the visual perspectives of others automatically has an innate origin (Surtees & Apperly, 2012).

Crucial evidence for the automaticity of perspective taking comes from the Dot Perspective Task (DPT; Samson, Apperly, Braithwaite, Andrews, & Bodley Scott, 2010). In this task, participants view a room in which a person is depicted, standing centrally, looking either leftwards or rightwards. Dots can appear on either the left wall of the room, the right wall, or both. At the start of each trial, participants are shown a number between 0 and 3. Their task is to decide, as quickly as possible, whether the total number of dots in the room matches the number they were shown at the start of the trial. On consistent trials the participant and the person can see the same number of dots, for example, two dots appear on the wall in front of the person (Figure 1a). On inconsistent trials, there is a mismatch between the number of dots visible to the person and the number of dots visible to the participant, for example, one dot may appear on the wall in front of the person and the other dot may appear on the wall behind the person (Figure 1b). Participants are faster to verify the number of dots they can see on consistent trials, than on inconsistent trials. This reaction time (RT) difference is referred to as the self-consistency effect. This self-consistency effect is cited as evidence that participants compute the level 1 visual perspective of others automatically, even when it impedes their task performance.

Figure-1

The automatic perspective taking account of the self-consistency effect has not gone unchallenged, however. According to a rival ‘submentalizing’ view, the self-consistency effect is a product of domain-general attention cueing (Heyes, 2014; Santiesteban, Catmur, Hopkins, Bird, & Heyes, 2014). Faces and bodies are known to be strong attention cues – participants orient their visuospatial attention toward locations implied by the gaze of another (Langton & Bruce, 1999) and by their body orientation (Vestner, Gray, & Cook, 2021). It is possible, therefore, that participants respond faster on consistent trials because the gaze and body orientation of the person depicted ensures that participants’ attention is quickly directed to the location of the to-be-counted dots. Conversely, on inconsistent trials, participants’ attention is directed to a wall that contains either none of the to-be-counted dots or only a subset of those dots. In order to count all of the dots, participants need to orient their attention back to the non-cued location.

Evidence for the attention cueing account was provided by Santiestiban and colleagues (2014) who replaced the avatar with an arrow stimulus (Figure 1c). The rationale for this manipulation was that, while arrows are highly effective attention cues (Kuhn & Kingstone, 2009; Tipples, 2002), they are inanimate and thus do not have a ‘visual perspective’. Santiesteban et al. (2014) found similar self-consistency effects with arrows and human avatars. In a follow-up study, Santiesteban, Kaur, Bird, and Catmur (2017) sought to assess whether the self-consistency effect produced by arrows and images of human actors are products of the same neurocognitive mechanism. Consistent with this view, the application of repetitive TMS to right temporoparietal junction (rTPJ) – an area of cortex known to be engaged during the original dot perspective task (Ramsey, Hansen, Apperly, & Samson, 2013; Schurz et al., 2015) – was found to modulate both effects to a similar degree. If one accepts that arrows are “non-social”, then these findings speak against the implicit mentalizing account of the DPT and support the attention cueing account; they suggest that stimuli that cue visuospatial attention produce the self-consistency effect, regardless of whether they possess mental states and a visual perspective.

However, the status of arrows as “non-social” has been contested (Furlanetto, Becchio, Samson, & Apperly, 2016). It is well-established that, under certain conditions, children and adults anthropomorphise geometric shapes (Abell, Happe, & Frith, 2000; Heider & Simmel, 1944; Over & Carpenter, 2009). Indeed, arrows may have stronger social connotations than other geometric shapes because they are a symbolic instruction from one human mind to another. As a result, children learn to understand them as ostensive or communicative cues (Pellicano & Rhodes, 2003; Wu, Tummeltshammer, Gliga, & Kirkham, 2014). It is also possible that the particular arrow stimuli employed by Santiestiban et al. (2014) encouraged anthropomorphism. In order to match the appearance of the avatar used in the social condition, the authors used arrows that appeared to ‘stand upright’ and then ‘hunch over’ at the top (Figure 1c). This feature may have inadvertently given the arrows the appearance of a human-like posture. It has been argued that the findings of Santiestiban (2014) are therefore compatible with both the automatic perspective taking account and the attention cueing account (Furlanetto et al., 2016).

In the present study, we revisit the question of whether the self-consistency effect seen on the DPT measures automatic perspective taking or domain-general attention cueing. To test these rival accounts, we take advantage of novel findings from the attention cueing literature. It has recently been shown that several common objects – including desk fans – cue observers’ visuospatial attention (Vestner, Over, Gray, & Cook, 2021). Importantly, unlike arrows, these inanimate objects are comprehensively ‘non-social’. For example, desk fans do not serve as ostensive, communicative signals and are less likely to be anthropomorphized, particularly when standing stationary (e.g., on a plinth). Should objects like desk fans produce the self-consistency effect, this would strengthen the argument that this effect is a product of attention cueing (Heyes, 2014; Santiesteban et al., 2014; Santiesteban et al., 2017). However, should these objects fail to produce the self-consistency effect, this would support the automatic perspective taking account (Samson et al., 2010).

2. Experiment 1

In our first set of experiments, we sought to replicate the self-consistency effect described by Samson et al. (2010) using photographic images of human actors (Experiment 1a) and desk fans (Experiment 1b). If the self-consistency effect described by Samson et al. (2010) is a product of automatic perspective taking, we should see the effect with human actors only; desk fans should not produce the effect. However, if the consistency effect is a product of attention cueing, then both types of stimulus should produce the effect.

Our procedure was based closely on the first experiment described by Samson et al. (2010). In this experiment, trials in which participants were required to verify the number of dots they could see (self trials) were interleaved with trials in which the participant was required to verify the number of dots the person could see (other trials). The authors observed a consistency effect on both types of trials: RTs were faster when the participants' perspective and the person's perspective were consistent, than when the two perspectives were inconsistent.

For our purposes, the key effect is the consistency effect seen on the self trials, where the perspective of the person depicted modulates the speed with which participants report their own perspective. It is this self-consistency effect that suggests that participants may compute the perspective of others even when it is detrimental to task performance. Although the consistency effect seen on other trials (hereafter, the other-consistency effect) is not the primary focus of the present study, we elected to retain the other trials, adhering to the design of the first experiment described by Samson et al (2010). Importantly, the presence of the other trials may encourage participants to attribute mental states to the person shown in the room scene (O'Grady, Scott-Phillips, Lavelle, & Smith, 2021). By 'stacking the deck' in favour of the automatic perspective taking hypothesis, we hoped to provide the sternest possible test of the attention cueing account.

The task used in the present study closely resembles that employed by Samson et al. (2010), with the following exceptions: 1) Whereas the experiment described by Samson et al. (2010) was conducted in the lab, the experiments described here were conducted online. This approach is increasingly common. Carefully designed online tests of cognitive and perceptual processing can yield high-quality data, indistinguishable from that collected in the lab (Crump, McDonnell, & Gureckis, 2013; Germine et al., 2012; Woods, Velasco, Levitan, Wan, & Spence, 2015). 2). In the experiment described by Samson et al. (2010), the authors used images of computer-generated avatars. Here, we employed photographs of real human actors, reasoning that participants are more likely to attribute mental states to 'real' actors. 3) In the Samson et al. (2010) paradigm, male participants viewed a male avatar and female participants viewed a female avatar. However, given that we attribute mental states to conspecifics irrespective of their sex/gender, male and female participants in our paradigm viewed both male and female actors in the room scene.

2.1. Experiment 1a (humans)

2.1.1. Methods

Forty participants (21 female, 19 male) with an age range of 18 to 54 (M_{age} = 30.5, SD_{age} = 9.2) were recruited through Prolific (https://www.prolific.com). Participants were only invited if their native language was English, if they were aged between 18 and 60 years-old, did not report any ongoing mental health conditions, and had a Prolific approval rating of at least 75%. The same criteria were applied in all of the experiments described below. Each of the samples described are independent – no-one participated in more than one experiment.

Sample size was determined *a priori*, informed by a power analysis conducted in G*Power, assuming a medium effect size (f = 0.25) and a target power of 0.8. This yielded a target sample size of 34, which we rounded up to 40. Ethical clearance was granted by the local ethics committee and the experiment was conducted in line with the ethical guidelines laid down in the 6th (2008) Declaration of Helsinki. All participants gave informed consent.

Images of six individuals (3 female, 3 male), viewed in profile, were sourced from the Adobe Stock Service. Individuals were shown facing left or right and were presented at a height of 9.5 cm, regardless of participants' screen size. The individuals were located centrally within an empty room. Red "dots" could appear on the left wall of the room, the right wall, or both, at the eye-level of the person depicted. The number of dots presented within the room could total 0, 1, 2, or 3. The dot arrangements were identical to those employed by Samson et al. (2010).

At the start of the experiment, participants were shown an image of the room scene accompanied by the following instructions: “Each trial of this experiment will feature a room like this with a person standing in it, and some red dots on the wall. You will be asked to count the dots either from your perspective (in the entire room) or from the perspective of the person (on the wall the person can see). If the number of dots matches the number you were shown before press ‘y’. If it doesn’t match, press ‘n’. Please try to be as fast as possible while still being accurate.”

Each trial started with a fixation cross (500ms) followed by an indication of the trial type (either “YOU” or “PERSON”) displayed for 750ms. “YOU” indicated that the participant should verify the number of dots they could see, whereas “PERSON” indicated that the participant should verify the number of dots the person depicted could see. Next, a digit prompt (0-3) appeared for 750ms against which the number of dots in the room was to be compared. The room scene appeared immediately after the offset of the digit prompt. Thereafter, participants had 2000ms to judge whether the digit shown at the start of the trial corresponded to the number of dots the person could see (other trials) or they could see (self trials). Participants registered their responses using the ‘y’ (yes) and the ‘n’ (no) key. Trial structure is illustrated in Figure 2a.

In total, participants completed 208 experimental trials: 2 levels of Perspective (other, self) × 2 levels of Consistency (consistent, inconsistent) × 2 levels of Digit Match (yes, no) × 26 trials in each cell of the design. The experiment was preceded by 26 practice trials. During the practice trials participants received feedback after each trial (either “correct”, “incorrect”, or “too slow”). During the experimental trials, participants only received feedback if their response was too slow. The entire experiment took approximately 25 minutes.

Consistent with the treatment of Samson et al. (2010), in all of the experiments described we analysed the RTs of “Yes” trials only; i.e., only those trials where the digit presented at the start of the trial matched the number of dots visible to the person (other trials) or the participant (self trials). Also consistent with the treatment of Samson et al. (2010), we excluded trials on which no dots were presented (16 in total, 2 in each cell of the design. These “filler” trials were included by Samson et al. (2010) to ensure that zero could be the correct answer on self trials. The data supporting all of our analyses can be accessed via OSF (https://osf.io/kzgsv/).

Figure-2

2.1.2. Results

Participants responded incorrectly on 4.2% of trials and too slowly on 0.6% of trials. Given the extremely low error-rate, our analysis focused on participants’ RTs. For the purpose of this analysis, trials where participants responded incorrectly or too slowly were excluded.

Participants’ RTs were subjected to ANOVA with Perspective (other, self) and Consistency (consistent, inconsistent) as within-subjects factors (Figure 3a). The analysis revealed a significant main effect of Consistency [$F(1,39) = 86.33$, $p < .001$, $\eta_p^2 = .689$]. As expected, we observed significant consistency effects on both other [$t(39) = 8.50$, $p < .001$, $d = 1.344$] and self trials [$t(39) = 4.88$, $p < .001$, $d = 0.771$]. The effect of consistency was larger for other trials, than for self trials [$F(1,39) = 8.21$, $p = .007$, $\eta_p^2 = .174$]. There was no main effect of Perspective [$F(1,39) = 0.36$, $p = .551$, $\eta_p^2 = .009$], suggesting that RTs on self and other trials were broadly comparable.

2.2. Experiment 1b (desk fans)

2.2.1. Methods

Forty participants (26 female, 14 male) with an age range of 18 to 57 ($M_{age} = 28.0$, $SD_{age} = 9.8$) were recruited through Prolific. Six different images of desk fans were chosen from various stock websites. In order to match the height of the human actors depicted in the previous experiment, the desk fans were shown sitting on top of a plinth (Figure 2b). The centre of each fan’s rotor was at the same height as the eyes of the person in Experiment 1a.

Trials in Experiment 1a started with either “YOU” or “PERSON” to indicate whether participants should count the dots visible from their own perspective, or only those dots visible to the person depicted in the room. In Experiment 1b, trials began with “YOU” or “OBJECT”. The wording of the instructions was amended to: “You will be asked to count the dots either from your perspective (in the entire room) or only the ones the object is facing towards. If the number of dots matches the number you were shown before press ‘y’. If it doesn’t match, press ‘n’. Please try to be as fast as possible while still being accurate.” In all other respects, the procedure was identical to Experiment 1a.

2.2.2. Results

Participants responded incorrectly on 5.1% of trials and too slowly on 0.8% of trials. Given the low error-rate (comparable to that seen in Experiment 1a), we again chose to focus on participants’ RTs. Once again, trials where participants responded incorrectly or too slowly were excluded for the purpose of this analysis.

Participants’ RTs were subjected to ANOVA with Perspective (other, self) and Consistency (consistent, inconsistent) as within-subjects factors (Figure 3b). The analysis revealed a significant main effect of Consistency [$F(1,39) = 80.24$, $p < .001$, $\eta_p^2 = .673$]. We observed significant consistency effects on both other [$t(39) = 12.50$, $p < .001$, $d = 1.977$] and self trials [$t(39) = 2.63$, $p = .012$, $d = 0.416$]. The effect of Consistency was larger for other trials, than for self trials [$F(1,39) = 18.69$, $p < .001$, $\eta_p^2 = .324$]. There was no main effect of Perspective [$F(1,39) = 0.21$, $p = .649$, $\eta_p^2 = .005$], suggesting that RTs on other and self trials were broadly comparable.

Figure-3

2.3. Cross-experiment comparison

Next, we sought to compare the strength of the self-consistency effect produced by human actors and desk fans. We ran an ANOVA with Stimulus (human actors, fans) as a between-subjects factor and Consistency (consistent, inconsistent) as a within-subjects factor. As expected, the analysis revealed a significant main effect of Consistency [$F(1,78) = 25.98$, $p < .001$, $\eta_p^2 = .250$]. Crucially, however, there was no main effect of Stimulus [$F(1,78) = 3.65$, $p = .060$, $\eta_p^2 = .045$], nor was there a

Stimulus × Consistency interaction [$F(1,78) = 0.95$, $p = .333$, $\eta_p^2 = .012$]. These results indicate that the strength of the self-consistency effects produced by human actors and desk fans did not differ significantly.

3. Experiment 2

In the experiments describe above we replicated the crucial self-consistency effect described by Samson et al. (2010) with human actors (Experiment 1a) and desk fans (Experiment 1b). The fact that we were able to replicate the self-consistency effect with inanimate objects that cue attention, argues against the implicit mentalizing hypothesis. Instead, these findings accord with the attentional cueing account.

The design of the present study was based as closely as possible on the first experiment described by Samson et al. (2010). It is well-established that within this design, the key manipulation of consistent vs. inconsistent on self trials is partially confounded by the spatial grouping of the to-be-counted dots (Santiesteban et al., 2014). On consistent trials, the dots are necessarily grouped together at a single location (on the side of the room implied by the directionality of the central stimulus). On inconsistent trials, however, to-be-counted dots are sometimes distributed across both walls (e.g., 2 on the left wall, 1 on the right wall).

It is possible, therefore, that slower RTs on inconsistent trials simply reflect the fact that the dots are on average easier to count on the spatially-grouped consistent trials, relative to the spatially-disparate inconsistent trials. If the self-consistency effect produced by our online paradigm is a product of the spatial grouping of the to-be-counted dots, this might explain why we see the effect both with images of people and inanimate desk fans.

We sought to interrogate this possibility in our second set of experiments. In addition to the Perspective and Consistency conditions employed in the first set of experiments, we included an additional self condition where participants were asked to report the number of dots from their perspective in the absence of a cueing stimulus. If the self-consistency effects described above are a product of the different configurations of dots in the consistent and inconsistent trials, we should also see the effect in this self (cue-absent) variant.

The arrangement of the dots in the consistent and inconsistent trials of the self (cue-absent) condition were identical to the arrangement of the dots in the consistent and inconsistent trials of the self (cue-present) condition. For ease of exposition, we therefore refer to trials in the cue-absent variant as “consistent” and “inconsistent”. Note, however, that the only sense in which these trials are “consistent” and “inconsistent” is that the spatial arrangement of the dots is identical to the arrangements used in the consistent and inconsistent conditions of the cue present variant.

3.1. Experiment 2a (humans)

Except for the addition of the self (cue-absent) trials, Experiment 2a was identical to Experiment 1a. Forty participants (26 female, 14 male) with an age range of 18 to 50 (M_{age} = 30.6, SD_{age} = 9.3) were recruited through Prolific. Whereas Experiment 1a comprised 208 trials and lasted ~25 minutes, Experiment 2a comprised 312 trials and lasted ~35 minutes.

Trials where participants responded incorrectly (5.2%) or too slowly (1.1%) were excluded. Participants’ RTs were subjected to ANOVA with Perspective (other, $\text{self}_{\text{cue-present}}$, $\text{self}_{\text{cue-absent}}$) and Consistency (consistent, inconsistent) as within-subjects factors (Figure 4a). The analysis revealed significant main effects of Perspective [$F(2,78) = 58.55$, $p < .001$, $\eta_p^2 = .600$] and Consistency [$F(1,39) = 95.64$, $p < .001$, $\eta_p^2 = .710$], and a significant Perspective × Consistency interaction [$F(2,78) = 22.63$, $p < .001$, $\eta_p^2 = .367$]. Subsequent analyses revealed significant simple interactions between Consistency and Perspective (other, $\text{self}_{\text{cue-present}}$) [$F(1,39) = 17.81$, $p < .001$, $\eta_p^2 = .314$], Consistency and Perspective (other, $\text{self}_{\text{cue-absent}}$) [$F(1,39) = 41.44$, $p < .001$, $\eta_p^2 = .515$], and Consistency and Perspective ($\text{self}_{\text{cue-present}}$, $\text{self}_{\text{cue-absent}}$) [$F(1,39) = 4.24$, $p = .046$, $\eta_p^2 = .098$]. We observed significant consistency effects on other [$t(39) = 8.88$, $p < .001$, d = 1.407] and self (cue-present) trials [$t(39) = 3.21$, $p = .003$, d = 0.51], but not on self (cue-absent) trials [$t(39) = 0.68$, $p = .499$, d = 0.107].

3.2. Experiment 2b (desk fans)

Except for the addition of the self (cue absent) trials, Experiment 2b was identical to Experiment 1b. Forty participants (26 female, 14 male) with an age range of 19 to 57 (M_{age} = 32.7, SD_{age} = 11.3) were recruited through Prolific. Experiment 2b comprised 312 trials and lasted ~35 minutes.

Trials where participants responded incorrectly (5.4%) or too slowly (0.8%) were excluded. Participants' RTs were subjected to ANOVA with Perspective (other, $self_{cue\text{-}present}$, $self_{cue\text{-}absent}$) and Consistency (consistent, inconsistent) as within-subjects factors (Figure 4b). The analysis revealed significant main effects of Perspective [$F(2,78) = 52.75$, $p < .001$, $\eta_p^2 = .575$] and Consistency [$F(1,39) = 45.13$, $p < .001$, $\eta_p^2 = .536$], and a significant Perspective × Consistency interaction [$F(2,78) = 26.13$, $p < .001$, $\eta_p^2 = .401$]. Subsequent analyses revealed significant simple interactions between Consistency and Perspective (other, $self_{cue\text{-}present}$) [$F(1,39) = 13.91$, $p = .001$, $\eta_p^2 = .263$], Consistency and Perspective (other, $self_{cue\text{-}absent}$) [$F(1,39) = 56.22$, $p < .001$, $\eta_p^2 = .590$], and Consistency and Perspective ($self_{cue\text{-}present}$, $self_{cue\text{-}absent}$) [$F(1,39) = 11.07$, $p = .002$, $\eta_p^2 = .221$]. We observed significant consistency effects on other [$t(39) = 7.91$, $p < .001$, d = 1.250] and self (cue-present) trials [$t(39) = 3.30$, $p = .002$, d = 0.522], but not on self (cue-absent) trials [$t(39) = 0.86$, $p = .398$, d = 0.135].

Figure-4

3.3. Cross-experiment comparison

Once again, we sought to compare the strength of the consistency effects produced on self (cue-present) trials by human actors and desk fans. We ran an ANOVA with Stimulus (human actors, fans) as a between-subjects factor, and Consistency (consistent, inconsistent) as a within-subjects factor. The analysis revealed a significant main effect of Consistency [$F(1,78) = 21.08$, $p < .001$, $\eta_p^2 = .213$]. There was no main effect of Stimulus [$F(1,78) = 0.48$, $p = .491$, $\eta_p^2 = .006$], nor a Stimulus × Consistency interaction [$F(1,78) = 0.29$, $p = .595$, $\eta_p^2 = .004$]. As we saw in our first set of experiments, the strength of the consistency effects produced by human actors and desk fans on self (cue present) trials did not differ significantly.

4. Experiment 3

Our results so far indicate that images of people and images of desk fans produce the self-consistency effect originally described by Samson et al (2010) and that these effects are not attributable to the different dot configurations on consistent and inconsistent trials. It remains possible, however, that the self-consistency effects produced by images of people, and by images of desk fans are products of qualitatively different mechanisms. Whereas the effect produced by images of people might be the product of automatic perspective taking, the effect produced by desk fans might be a product of attention cueing (e.g., O'Grady et al., 2021). We sought to investigate this possibility in our final two experiments.

In Experiment 3a, participants completed both versions of the task - human actors and desk fans. If the self-consistency effects seen with images of people and images of desk fans are products of qualitatively different mechanisms, then one might expect little or no correlation between participants' susceptibility to the two effects. However, if the self-consistency effects produced by images of people and by images of desk fans are qualitatively similar, then individuals' susceptibility to one effect ought to correlate with their susceptibility to the other.

In Experiment 3b, participants completed the dot perspective task with human actors twice, to help us interpret the findings from Experiment 3a. If the effects seen with human actors and desk fans are products of a common mechanism, the strength of the correlation seen in Experiment 3a should approach the test-retest correlation of the human actors task. Should the correlation seen in Experiment 3a fall substantially below the test-retest correlation of the human actors task, it would suggest that the mechanisms may still differ, even if the former reaches statistical significance. Sample size (N = 120) was determined *a priori*, informed by a power analysis conducted in G*Power, assuming a correlation of r = 0.25 and a target power of 0.8.

4.1. Experiment 3a

One hundred and twenty participants (52 female, 67 male, 1 nonbinary) with an age range of 18 to 59 (M_{age} = 31.8, SD_{age} = 10.7) were recruited through Prolific. The social and non-social tasks were identical to those described in Experiment 1a and Experiment 1b, respectively. The order in which participants completed the tasks was counterbalanced. Each task comprised 208 trials (~25 mins). Although the other-consistency effects produced by human actors and desk fans were not the primary focus of the present study, we retained the other trials as they serve to render the central stimulus salient (O'Grady et al., 2021).

Human actors. Trials where participants responded incorrectly (5.6%) or too slowly (1.1%) were excluded. Participants' RTs were subjected to ANOVA with Perspective (other, self) and Consistency (consistent, inconsistent) as within-subjects factors, and Order (actors first, desk fans first) as a between-subjects factors (Figure 5a). The analysis revealed a significant main effect of Consistency [$F(1,119) = 153.98$, $p < .001$, $\eta_p^2 = .566$]. We observed significant consistency effects on both other [$t(119) = 13.75$, $p < .001$, $d = 1.255$] and self trials [$t(119) = 4.48$, $p < .001$, $d = 0.409$]. The effect of Consistency was larger for other trials, than for self trials [$F(1,119) = 62.16$, $p < .001$, $\eta_p^2 = .345$]. The main effect of Perspective did not reach significance [$F(1,119) = 3.70$, $p = .057$, $\eta_p^2 = .030$]. There was no main effect of Order [$F(1,118) = 0.145$, $p = .704$, $\eta_p^2 = .001$] and none of the interactions with Order reached significance (all *F*s < 0.67, all *p*s > .416).

Desk fans. Trials where participants responded incorrectly (5.9%) or too slowly (1.5%) were excluded. Participants' RTs were subjected to ANOVA with Perspective (other, self) and Consistency (consistent, inconsistent) as within-subjects factors, and Order (actors first, desk fans first) as a between-subjects factors (Figure 5b). The analysis revealed a significant main effect of Consistency [$F(1,119) = 210.35$, $p < .001$, $\eta_p^2 = .641$]. We observed significant consistency effects on both other [$t(119) = 15.41$, $p < .001$, $d = 1.407$] and self trials [$t(119) = 4.94$, $p < .001$, $d = 0.451$]. The effect of Consistency was larger for other trials, than for self trials [$F(1,119) = 93.08$, $p < .001$, $\eta_p^2 = .441$]. We also observed a main effect of Perspective [$F(1,119) = 5.94$, $p = .016$ $\eta_p^2 = .048$], whereby participants responded faster on self trials than on other trials. There was no main effect of Order [$F(1,118) = 0.13$, $p = .721$, $\eta_p^2 = .001$] and none of the interactions with Order reached significance (all *F*s < 1.90, all *p*s > .170).

For the purpose of the correlational analyses, each individual's self-consistency effect was taken to be the difference between their mean RT on inconsistent self trials and their mean RT on consistent self trials. Using this measure, we observed a significant correlation between the self-consistency effects produced by human actors and by desk fans [N = 120, r_p = .453, p < .001] (Figure 6a). For the sake of completeness, we also calculated the correlation between the other-consistency effects produced by human actors and desk fans. This was also significant [N = 120, r_p = .335, p < .001].

Figure-5

4.2. Experiment 3b

One hundred and twenty participants (65 female, 55 male) with an age range of 18 to 59 (M_{age} = 30.6, SD_{age} = 10.2) were recruited through Prolific. All participants completed the human actors version of the dot perspective task twice. In all other respects, the procedure was identical to Experiment 3a.

First attempt. Trials where participants responded incorrectly (5.5%) or too slowly (1.1%) were excluded. Participants' RTs were subjected to ANOVA with Perspective (other, self) and Consistency (consistent, inconsistent) as within-subjects factors (Figure 5c). The analysis revealed a significant main effect of Consistency [F(1,119) = 170.49, p < .001, η_p^2 = .589]. We observed significant consistency effects on both other [t(119) = 13.73, p < .001, d = 1.254] and self trials [t(119) = 6.08, p < .001, d = 0.555]. The effect of Consistency was larger for other trials, than for self trials [F(1,119) = 31.53, p < .001, η_p^2 = .209]. We also observed a main effect of Perspective [F(1,119) = 10.51, p = .002, η_p^2 = .081], whereby participants responded faster on self trials than on other trials.

Second attempt. Trials where participants responded incorrectly (5.4%) or too slowly (1.2%) were excluded. Participants' RTs were subjected to ANOVA with Perspective (other, self) and Consistency (consistent, inconsistent) as within-subjects factors (Figure 5d). The analysis revealed a significant main effect of Consistency [F(1,119) = 167.89, p < .001, η_p^2 = .585]. We observed significant consistency effects on both other [t(119) = 13.31, p < .001, d = 1.215] and self trials [t(119) = 4.50, p < .001, d = 0.411]. The effect of Consistency was larger for other trials, than for self trials

[F(1,119) = 41.15, p < .001, η_p^2 = .257]. The main effect of Perspective did not reach significance [F(1,119) = 1.25, p = .265, η_p^2 = .010].

Once again, participants' self-consistency effect was taken to be the difference between their mean RT on inconsistent self trials and their mean RT on consistent self trials. Using this measure, we observed a significant correlation between the strength of the self-consistency effect seen on participants' first attempt and on their second attempt [N = 120, r_p = .431, p < .001] (Figure 6b). The correlation seen between the self-consistency effects produced by human actors and desk fans (r_p = .453) did not differ significantly from this estimate of the test-retest correlation of the human actors task (r_p = .431) [z = .209, p = .834].

For the sake of completeness, we also examined the test-retest correlation of the other-consistency effect using a similar method. The correlation observed [N = 120, r_p = .514, p < .001] did not differ significantly from the correlation between the other-consistency effects produced by human actors and desk fans (r_p = .335) [z = 1.680, p = .093].

Figure-6

5. General discussion

5.1. The self-consistency effect

There is an influential claim in the social cognition literature that adults automatically compute the visual perspective of others (Apperly & Butterfill, 2009). Key evidence for this view comes from the self-consistency effect seen on the DPT (Samson et al., 2010). It is argued that i) participants automatically compute the visual perspective of the person shown in the scene, and ii) respond slowly on inconsistent self trials because there is a mismatch between their own perspective and that of the other person. Evidence that participants compute the perspective of others in situations where it hinders their performance, would appear to provide strong support for the operation of automatic perspective taking. However, this interpretation has been challenged. According to a rival submentalizing account, the self-consistency effect is a product of domain-general attention cueing (Heyes, 2014; Santiesteban et al., 2014). In other words, the RT cost on inconsistent trials may reflect the fact that participants' attention is directed away from some or all of the to-be-counted dots.

The present study sought to test these rival accounts by examining whether desk fans also produce the self-consistency effect seen on the DPT. Desk fans have recently been shown to cue visuospatial attention; participants are faster to identify target letters shown at locations cued by the directionality of fans, than at non-cued locations (Vestner, Over, et al., 2021). Nevertheless, desk fans are unambiguously non-social; they are inanimate objects that do not possess mental states and cannot have a "visual perspective". Unlike arrows, desk fans do not serve as ostensive communicative signals are not easily anthropomorphized, particularly when standing stationary (e.g., on a plinth). Should fans produce the self-consistency effect, we reasoned that this would provide clear evidence in favour of the domain-general attention cueing account. This is precisely what we observed.

In our first two experiments, we found that images of desk fans produced clear self-consistency effects of comparable strength to those induced by images of people. In our third experiment, we compared the individual differences seen on the two versions of the task to determine whether the self-consistency effects induced by images of fans and people are products of a common mechanism. In a sample of 120 participants, we found that individuals' susceptibility to the effect induced by fans, correlated significantly with their susceptibility to the effect induced by human actors (r_p = .453). Importantly, the strength of this correlation was indistinguishable from the test-retest correlation of the human actors variant (r_p = .431). This finding suggests that the self-consistency effects seen with fans and human actors are products of a common mechanism.

Together, these results provide strong support for the submentalizing account of the self-consistency effect seen on the DPT. Consistent with the view that the effect is a product of domain-general attention cueing, unambiguously non-social objects (desk fans) produce the effect despite the fact that they do not possess mental states and cannot have a visual perspective. This conclusion accords with previous findings that the self-consistency effect shows little or no modulation by the ingroup-outgroup relationship between the participant and the individual depicted within the scene

(Simpson & Todd, 2017). It is also consistent with evidence that the effect shows little attenuation when a barrier is positioned within the scene that would prevent the human actor from viewing the to-be-counted dots (Cole, Atkinson, Le, & Smith, 2016; Langton, 2018), or when the actor within the scene is shown wearing opaque goggles (Conway, Lee, Ojaghi, Catmur, & Bird, 2017). If the self-consistency effect revealed the automatic computation of the actor's visual perspective, one might expect these manipulations to abolish the effect. Instead, these results are more consistent with an attentional cueing account.

The self-consistency effect seen on the DPT represents the key line of behavioral evidence for the hypothesis that we automatically compute the visual perspective of other people (Apperly & Butterfill, 2009). While our data suggest that this task does not measure automatic perspective taking, we are unable to make strong claims about whether automatic perspective taking occurs in other contexts. Indeed, we note that results have been obtained using other paradigms that appear to support the existence of automatic perspective taking. In particular, it has recently been reported that we can "borrow" the perspective of other people in order to process letter targets encountered in non-canonical orientations more efficiently (Ward, Ganis, & Bach, 2019). For example, participants are slower to judge whether letters are written correctly when target items are rotated 90° clockwise. However, the detrimental effects of this rotation are attenuated if another person is depicted on the left of the display, for whom this rotated target would now appear in its canonical orientation. This finding is consistent with the view that the spontaneous computation of the other's visual perspective may augment our own perceptual decisions when our viewpoint is suboptimal.

In light of the results described here and those seen previously (Cole et al., 2016; Conway et al., 2017; Langton, 2018; Santiesteban et al., 2014; Santiesteban et al., 2017), it seems unlikely that findings from the DPT reflect the automatic computation of others' visual perspective. In this context, the findings from the rotated target paradigm (Ward et al., 2019) are crucial. It is important that future work interrogates whether we spontaneously 'borrow' the visual perspectives of other people (the authors' interpretation), or whether this result might be better explained by a simpler 'submentalizing' mechanism (Heyes, 2014). One interesting possibility is that the presence of the other person aids perceptual decision making by helping participants establish a cardinal axis around which the features of the to-be-judged item can be encoded. If this suggestion is correct, it may be possible to replicate the effect with non-social stimuli that also help participants establish a cardinal axis. If the automatic perspective taking view is correct, however, it will not be possible to replicate the effect with non-social stimuli.

5.2. The other-consistency effect

The focus of the present paper is the self-consistency effect. This is the effect that has been cited – seemingly in error – as key evidence of automatic perspective taking (e.g., O'Grady et al., 2021; Samson et al., 2010; Simpson & Todd, 2017; Surtees & Apperly, 2012). In all of our experiments, however, we were also able to replicate the other-consistency effect described by Samson and colleagues (2010), whereby participants are slower to verify the number of dots seen by the human actor, when the total differs from the number of dots visible to the participant. Interestingly, our desk fan stimuli also produced this other-consistency effect; i.e., participants were slower to verify the number of dots on the wall cued by the fan, when there was a mismatch with the total number of dots they could see.

On reflection, it is perhaps unsurprising that participants struggled to inhibit their own perspective on the other trials of the social and non-social versions of the task. Our own perspective is inferred quickly, automatically (i.e., in a manner that is hard to inhibit), and is highly salient. Typically, the other-consistency effect is stronger than the self-consistency effect (Samson et al., 2010; Surtees & Apperly, 2012) and has been described in children and adults alike (Surtees & Apperly, 2012). Evidence of related egocentric biases have been described in a range of experimental tasks (Birch & Bloom, 2004; Sui & Humphreys, 2015; Symons & Johnson, 1997). Consistent with a prepotent characterization, neuropsychological patients have been described who struggle to inhibit their own perspective (e.g., Samson, Apperly, Kathirgamanathan, & Humphreys, 2005)

The fact that we observed the other-consistency effect with inanimate desk fans at first appears hard to reconcile with previous reports that this effect is modulated by the ingroup-outgroup relationship between the participant and the individual depicted within the room scene (Simpson & Todd, 2017). For example, participants found it easier to inhibit their own perspective when reporting the perspective of an out-group avatar (the mascot of a rival university) than when reporting the perspective of an in-group avatar (their own university mascot). On the face of it, such a result suggests a rich explanation of the other-consistency effect based on visual perspective taking. However, this result may also be understood in terms of task-switching and response inhibition. As is typical when using the DPT, self and other trials were interleaved in the experiment described by Simpson and Todd (2017). Participants were given a signal at the start of the trial that indicated whether they should respond based on their own perspective or the perspective of the mascot. On in-group other trials, it is conceivable that the in-group mascot effectively acted as a "self" signal that contradicted the foregoing "other" cue, increasing response competition. Conversely, on out-group other trials the out-group mascot may have acted as an extra "other" signal that reinforced the foregoing "other" cue, reducing response competition.

5.3. Limitations

It is important to consider the limitations of our approach. The present study was conducted online, an approach that is increasingly common. Carefully-designed online tests of cognitive and perceptual processing can yield high-quality data, indistinguishable from that collected in the lab (Crump et al., 2013; Germine et al., 2012; Woods et al., 2015). To give recent examples from our own research, we have found that online testing has produced clear, replicable results in visual search and attention cueing experiments (Gray et al., 2020; Vestner, Over, et al., 2021), and studies of visual illusions (Bunce, Gray, & Cook, 2021; Gray et al., 2020). However, this approach also has some well-known limitations. For example, it is not easy to control the testing environment, participants' viewing distance, or their monitor settings.

To date, there has been relatively little investigation of the psychometric properties of the DPT. The results from Experiment 3b suggest that our measure of the self-consistency effect had relatively modest test-retest reliability (r_s = .431). It is possible that lab-based paradigms may exhibit higher levels of reliability. However, it has previously been noted that many classic RT paradigms – including Stroop interference (Stroop, 1935), the Eriksen flanker effect (Eriksen & Eriksen, 1974), and the Navon task (Navon, 1977) – produce unreliable estimates of individuals' susceptibility, despite producing highly-reliable effects at the group level (Hedge, Powell, & Sumner, 2018). Further work is required to determine whether the self-consistency effect seen on the DPT is simply prone to measurement noise.

5.4. Conclusion

In conclusion, the results described here provide clear support for the submentalizing account of the self-consistency effect seen on the DPT. In two experiments, we found that desk fans – a class of non-social objects known to cue visuospatial attention – produce the self-consistency effect despite the fact that they do not possess mental states and cannot have a visual perspective. In a third experiment, we observed a clear correlation between individuals' susceptibility to the self-consistency effects induced by fans and those induced by human actors. Together, these findings suggest that the self-consistency effect is a product of domain-general attention cueing, not the (automatic) computation of visual perspective.

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Figures

Figure 1

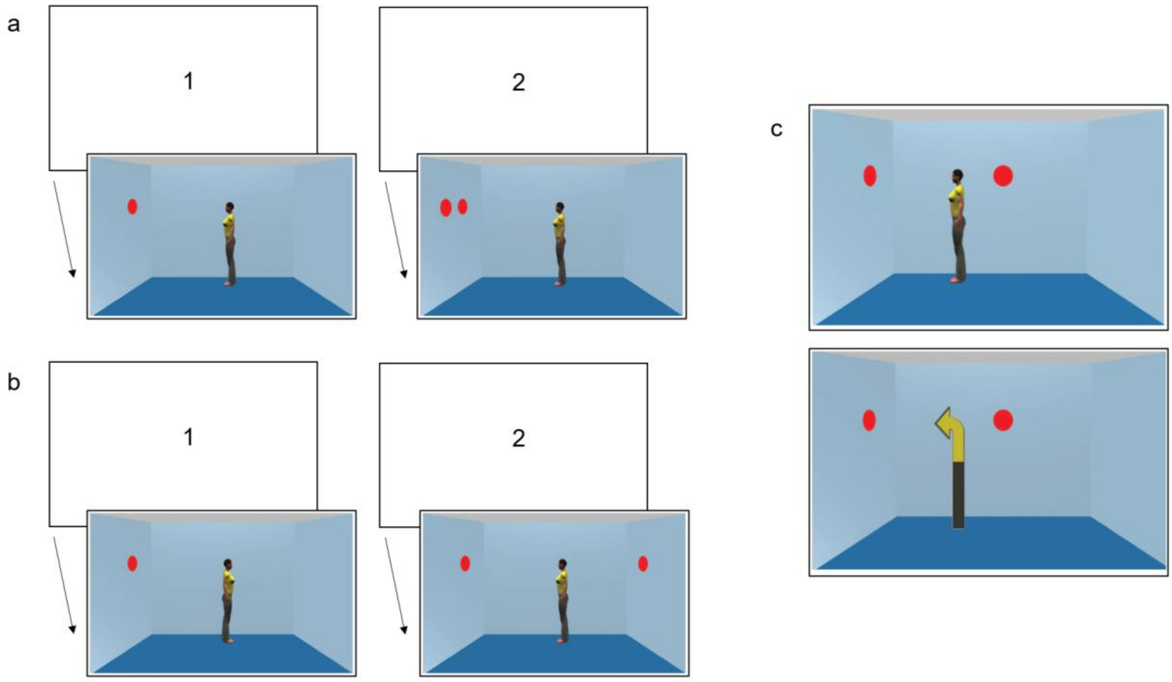


Figure 1. In the dot perspective task (DPT), participants are faster to verify the number of dots they can see when the person depicted sees the same number of dots (a), than when the person depicted sees a different number of dots (b). This RT difference is referred to as the self-consistency effect. This finding is consistent with the view that we struggle to ignore the perspective of others even when it is task-irrelevant and impedes ongoing task performance. However, Santiestiban and colleagues (2014) were able to replicate the self-consistency effect using arrows (c), raising the possibility that the effect is a product of domain-general attention cueing.

Figure 2

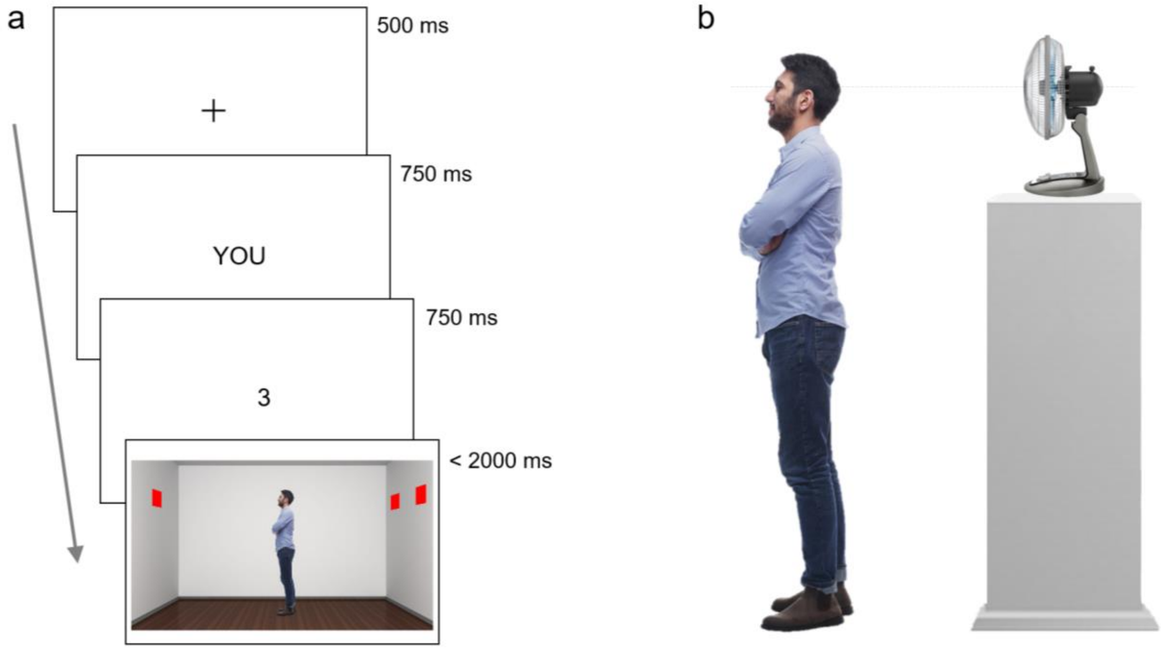


Figure 2. (a) Illustration of the trial procedure. (b) Example cueing stimuli from Experiment 1a (human actors) and Experiment 1b (desk fans).

Figure 3

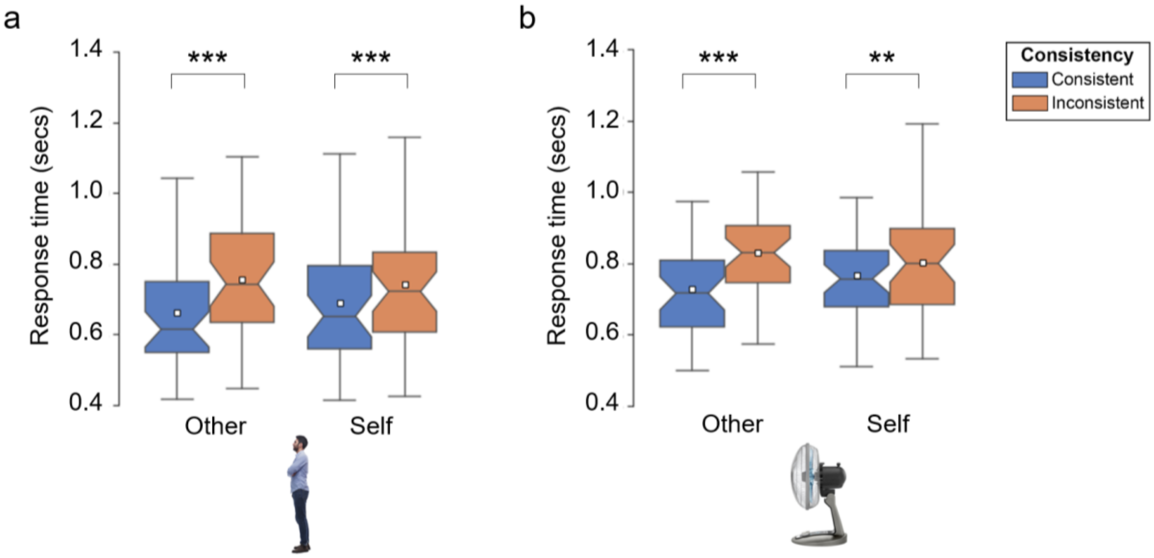


Figure 3. (a) Results of Experiment 1a. (b) Results of Experiment 1b. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5* interquartile range. White squares denote the mean. *** denotes significance at $p < .001$. ** denotes significance at $p < .025$.

Figure 4

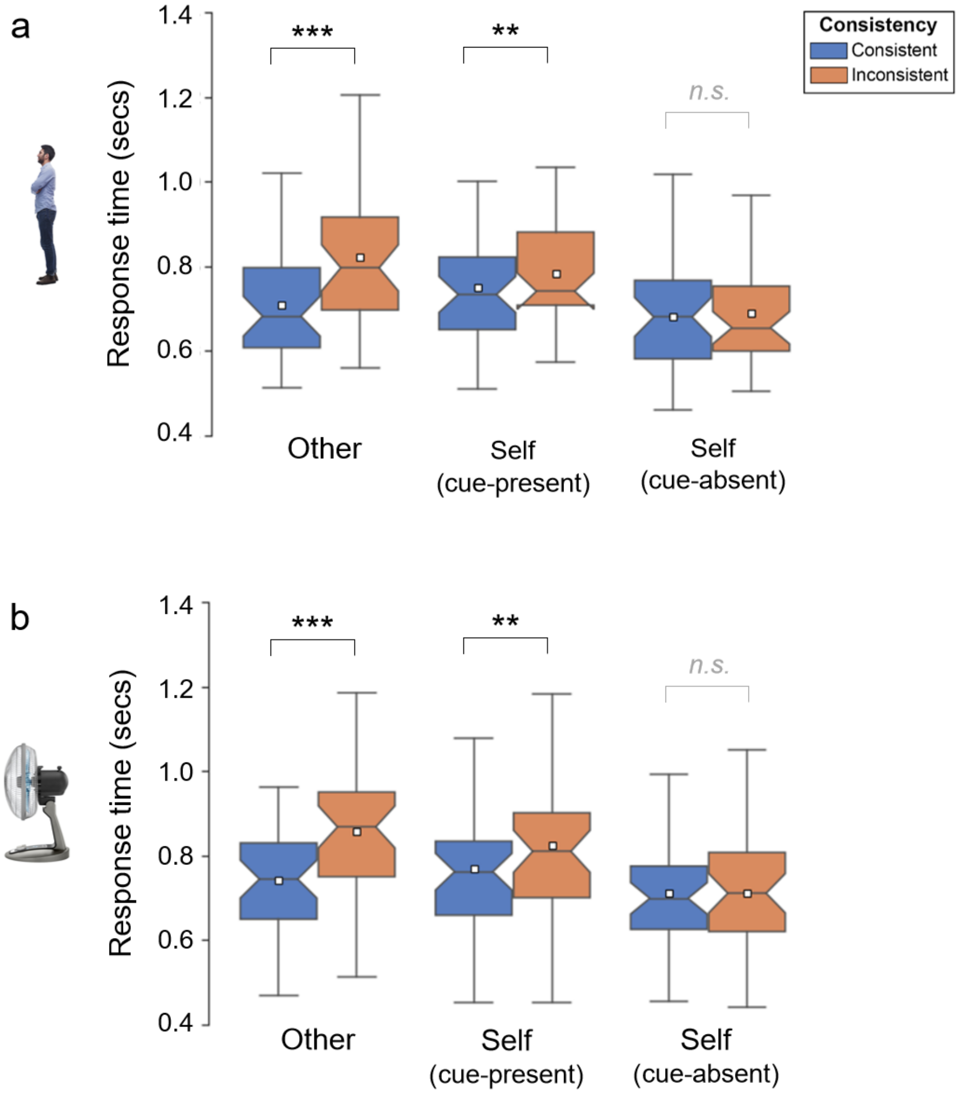


Figure 4. (a) Results of Experiment 2a. (b) Results of Experiment 2b. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5* interquartile range. White squares denote the mean. *** denotes significance at $p < .001$. ** denotes significance at $p < .025$.

Figure 5

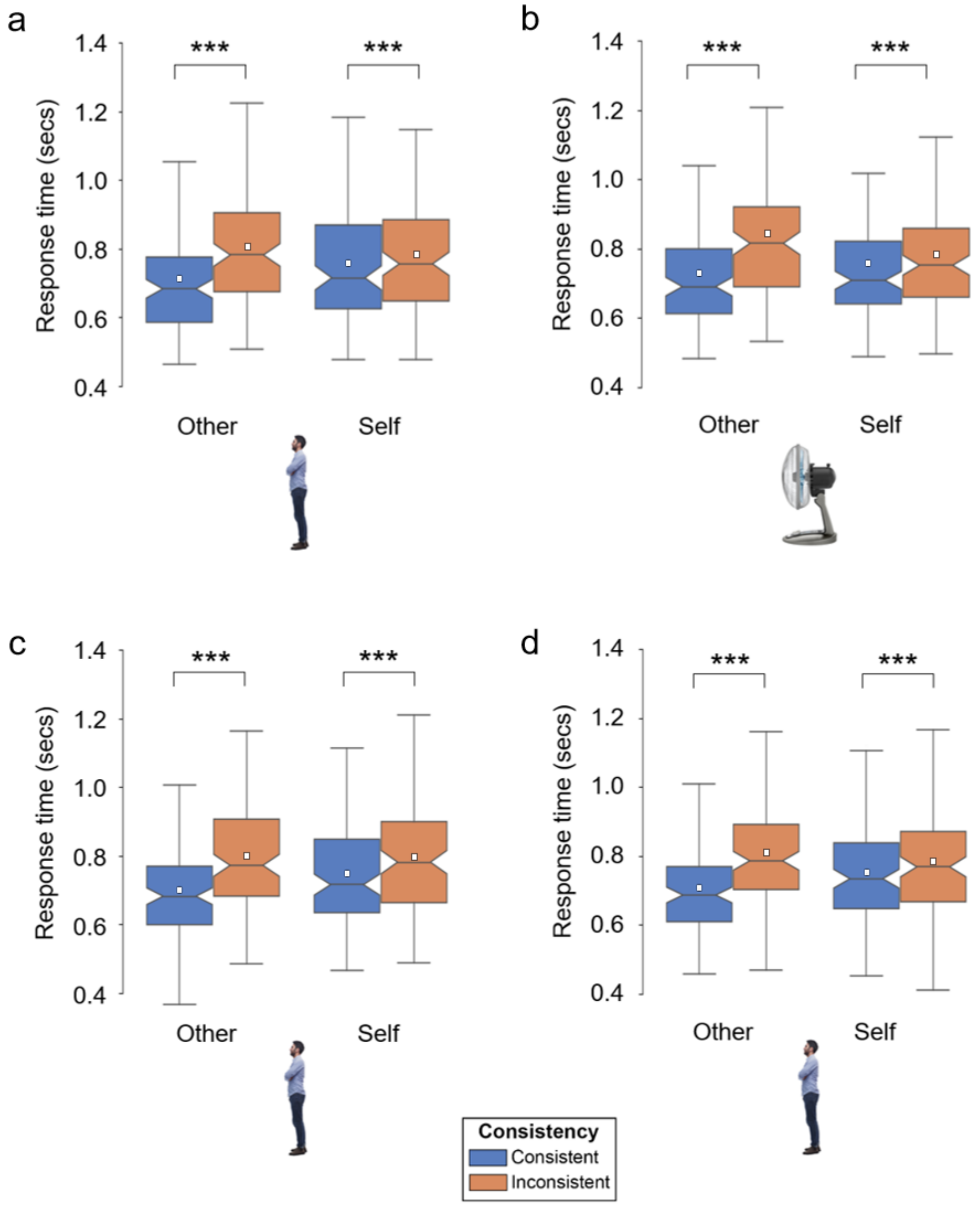
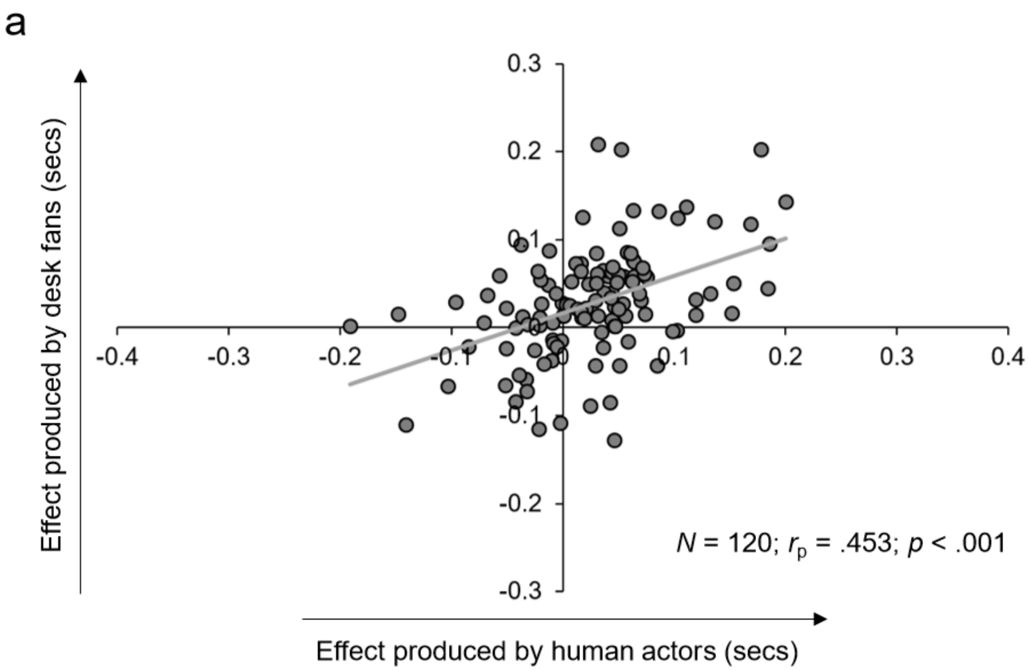


Figure 5. (a) Results from the fans condition of Experiment 3a. (b) Results from the human actor condition of Experiment 3b. (c) Results from participants' first attempt in Experiment 3b. (d) Results from participants second attempt in Experiment 3b. Boxes indicate inter-quartile range. Notches indicate confidence interval of the median. Whiskers indicate 1.5* interquartile range. White squares denote the mean. *** denotes significance at $p < .001$. ** denotes significance at $p < .025$.

Figure 6



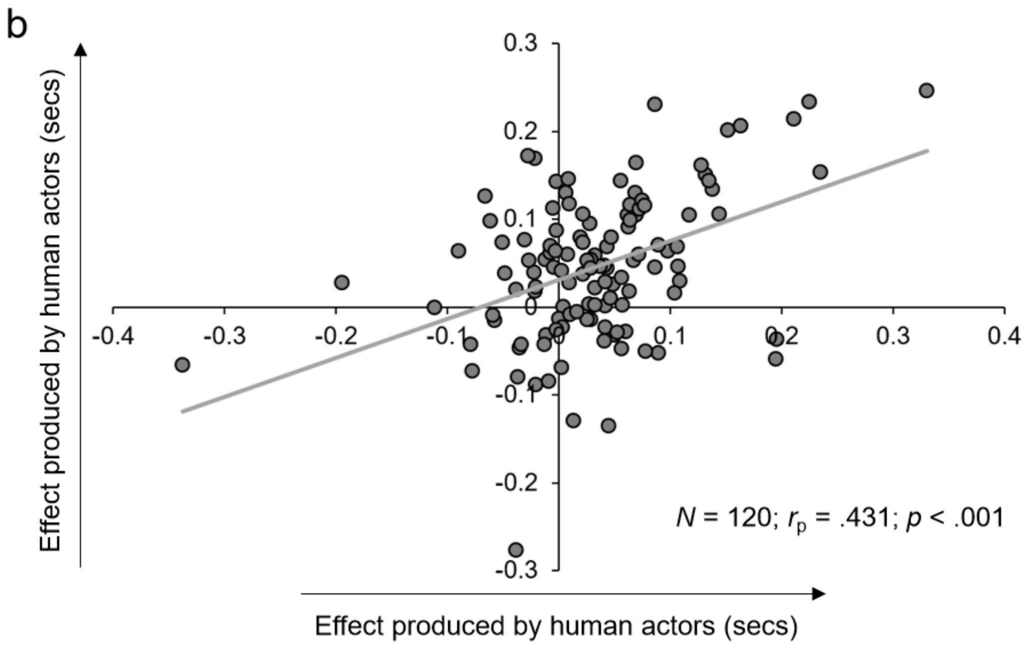


Figure 6. (a) Results from Experiment 3a. The order in which participants completed the two tasks was counterbalanced. (b) Results from Experiment 3b. The effects observed on participants' first and second attempt are shown on the horizontal and vertical axes, respectively.