Dissociating Processes Underlying Level-1 Visual Perspective Taking in Adults

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Abstract

Although reasoning about other people's mental states has typically been thought to require effortful deliberation, evidence from indirect measures suggests that people may implicitly track others' perspectives, spontaneously calculating what they see and know. We used a process-dissociation approach to investigate the unique contributions of automatic and controlled processes to level-1 visual perspective taking in adults. In Experiment 1, imposing time-pressure reduced the ability to exert control over one's responses, but it left automatic processing of a target's perspective unchanged. In Experiment 2, automatic processing of a target's perspective was greater when the target was a human avatar versus a non-social entity, whereas controlled processing was relatively unaffected by the specific target. Our findings highlight the utility of a process-dissociation approach for increasing theoretical precision and generating new questions about the nature of perspective taking.

Keywords: automaticity; implicit mentalizing; process dissociation; theory of mind; visual perspective taking

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Reasoning about what other people see, think, know, and want is crucial for making sense of what they say and do and for predicting their future actions. Ascribing such mental states to others has commonly been thought to require effortful deliberation, which may explain why, at times, even neuro-typical adults err when making explicit judgments about others' perspectives (Birch & Bloom, 2004; Nickerson, 1999). These occasional struggles with explicit mental-state ascription notwithstanding, evidence from *indirect* measures suggests that both adults and children may *implicitly* track others' perspectives (e.g., Kovács et al., 2010; Schneider et al., 2012; Surtees & Apperly, 2012). Our aim here was to gain a better understanding of the processes underlying implicit visual perspective taking in adults.

Automatic Visual Perspective Taking?

Samson et al. (2010) recently introduced a level-1¹ visual perspective-taking (hereafter, L1-VPT) task that affords both direct and indirect measures of perspective taking. In this task, adults view a human avatar standing in a room with dots on the walls. On some trials, the avatar and participants can see the same number of dots; on other trials, the avatar cannot see some of the dots that participants can see. Two interference effects commonly emerge in this task: First, on trials where participants judge the avatar's perspective, they have difficulty doing so if their own perspective conflicts with that of the avatar. This effect – *egocentric intrusion* – resembles egocentric biases found on other direct measures requiring explicit judgments of others' perspective (e.g., Epley et al., 2004; Keysar et al., 2003; Todd et al., 2011, 2015). Second, on trials where participants report their own perspective, they have difficulty doing so if the avatar has a different perspective; that is, processing of the avatar's perspective interferes with reporting

¹Level-1 VPT entails understanding *whether* someone can see something or not; this can be contrasted with level-2 VPT, which entails understanding *how* that something appears to the person (Flavell et al., 1981).

one's own. This latter effect – *altercentric intrusion* – is commonly thought to provide an indirect measure of the relatively automatic calculation of others' visual perspectives (e.g., Baker et al., 2016; Bukowski et al., 2015; Furlanetto et al., 2016; Qureshi et al., 2010; Ramsey et al., 2013), an interpretation that aligns with theoretical claims of an implicit mentalizing system that tracks others' perspectives rapidly and effortlessly (Apperly & Butterfill, 2009; for non-mentalizing alternative interpretations of altercentric-intrusion effects, see Cole et al., 2015, 2016; Santiesteban et al., 2014).

One potential problem with interpreting altercentric-intrusion effects on a behavioral task as reflecting automatic perspective tracking is that no single task – nor a set of trials in a task – provides a “pure” measurement of automatic processing (Jacoby, 1991). Thus, rather than assuming that a single task captures a single process (i.e., “task-dissociation” approach; see Payne, 2001), we instead assume that both automatic *and* controlled processes contribute to the strength of altercentric-intrusion effects in behavior (and, indeed, to performance on any measure). Importantly, we identify automatic processing influences on task performance as our core construct of interest (i.e., automatic altercentrism) and distinguish it from controlled processing, which may also influence performance on the L1-VPT task. It is possible that, in some cases, controlled processes and automatic processes might have opposing influences on L1-VPT task performance, potentially masking automatic perspective tracking (we return to this issue in the Discussion). Claims of automaticity, therefore, require separating the unique contributions of these processes to task performance (Payne & Cameron, 2014).

Process Dissociation and Visual Perspective Taking

A prominent technique for decomposing component processes in a single task is the process-dissociation procedure (PDP). Originally developed to disentangle automatic versus

controlled influences on memory (Jacoby, 1991), variants of the PDP have been used to estimate processes underlying task performance in various other domains, including decision-making under uncertainty (Ferreira et al., 2006), moral judgment (Cameron et al., in press; Conway & Gawronski, 2013), and racial stereotyping (Payne, 2001; Todd et al., 2016). Unlike task-dissociation approaches, which assume that indirect (or implicit) measures capture only automatic processes, the PDP (and other process-dissociation approaches; e.g., Conrey et al., 2005) assumes that automatic and controlled processes can be differentiated in a single task by creating conditions that put these processes both in concert and in opposition. The PDP specifies *a priori* how automatic and controlled processes interact to drive behavior in a particular task; thus, it uses task performance to estimate the probability of each process operating.

Applying the logic of PDP to the L1-VPT task, when participants and the avatar can see the same number of dots (i.e., consistent trials), automatically calculating the avatar's perspective and deliberately reporting one's own perspective lead to the same response. The probability of responding correctly is the probability of controlled processing (C) operating plus the probability of automatic processing (A) operating when control fails (1-C):

$$P(\text{correct}|\text{consistent trials})=C+A(1-C) \quad (1)$$

When the number of dots visible to the avatar differs from the number visible to participants (i.e., inconsistent trials), however, automatically calculating the avatar's perspective and deliberately reporting one's own perspective lead to different responses. The probability of an incorrect response here is the probability of automatic processing operating when control fails:

$$P(\text{incorrect}|\text{inconsistent trials})=A(1-C) \quad (2)$$

With these two equations, one can solve algebraically for separate estimates of C and A:

$$C=P(\text{correct}|\text{consistent trials})-P(\text{incorrect}|\text{inconsistent trials}) \quad (3)$$

$$A = P(\text{incorrect} | \text{inconsistent trials}) / (1 - C) \quad (4)$$

The PDP, as we apply it here to understand altercentric-intrusion effects, characterizes automaticity and control in terms of intentionality (see also Payne, 2001). Controlled processes are those in which one's responses conform to one's performance intentions; thus, the C parameter reflects accurately reporting one's own perspective. Automatic processes, in contrast, are those that operate regardless of whether they facilitate or interfere with intentional performance. On a PDP-based account of altercentric-intrusion effects, the A parameter is of focal interest for claims about automatic visual perspective taking—this parameter reflects calculation of the target's perspective despite intending only to report one's own perspective.

Overview of Experiments

In two experiments, we used the PDP to estimate component processes underlying altercentric-intrusion effects in L1-VPT. A primary advantage of the PDP is that it can quantify automatic and controlled processes; however, it cannot specify the conditions under which these processes operate. Thus, claims about specific operating conditions (e.g., resource efficiency) must be tested by manipulating theoretically-relevant processes. Our general strategy here was to create experimental conditions that, based on prior work, should affect one component process (but not the other) in a particular direction.

In Experiment 1, we manipulated the response-deadline in the L1-VPT task. We reasoned that a fast deadline should reduce the opportunity to exert control over one's responses (Cameron et al., in press; Conrey et al., 2005; Payne, 2001), thereby weakening controlled processing but leaving automatic processing of the avatar's perspective unchanged. In Experiment 2, we manipulated the specific target in the L1-VPT task. Based on prior work suggesting that altercentric-intrusion effects are stronger for social versus non-social targets (e.g., Nielsen et al.,

2015; Samson et al., 2010; Todd & Simpson, 2016), we reasoned that automatic processing of a target's perspective should be greater if the target is a human avatar versus a non-human entity, whereas controlled processing should be relatively unaffected by the specific target.

Experiment 1: Time-Pressure

Method

Native English-speaking undergraduates ($N=125$) participated for course credit. Data were excluded from 6 participants with below-chance task performance, which could indicate confusion about response-key mappings or task instructions. The PDP assumes that parameter estimates range from 0 to 1 (Jacoby, 1991); thus, data from 2 participants (both in the short-deadline condition) with negative C estimates, which violate PDP assumptions (i.e., more errors on consistent than inconsistent trials), were excluded. Computer malfunctions resulted in data loss for 2 other participants, leaving a final sample of 115 (80 women, 34 men, 1 unreported).

Participants completed an L1-VPT task (Samson et al., 2010). They saw a room with red dots on the left and right walls. A human avatar stood in the center of the room facing left or right. On *other* trials, participants responded from the avatar's perspective; on *self* trials, they reported their own perspective. Additionally, on *consistent* trials, the number of dots visible to the avatar was identical to the number visible to participants; on *inconsistent* trials, the avatar could not see some of the dots that were visible to participants.

Each trial began with a fixation cross (500 ms), followed by a cue ("YOU" or "HE") indicating whose perspective to respond from (750 ms), and then another cue (0–3) indicating the number of dots to verify (750 ms). Finally, the room appeared (on screen until participants responded). Participants' objective was to verify if the number of visible dots matched or mismatched the given number by pressing one of two response keys as quickly as possible.

Match and mismatch trials occurred with equal frequency, but, as is customary in research using this task (see Samson et al., 2010, for details), only match trials were analyzed (Figure 1 displays the different types of match trials).

Figure 1. Trial examples on the L1-VPT task (match trials only). Participants verified if a given number (0–3) matched the number of dots visible either from their own perspective (“YOU”) or from the avatar’s perspective (“HE”). The number of dots visible from each perspective was either the same (consistent) or different (inconsistent). (Not pictured are mismatch trials where the number of dots visible did not match the assigned perspective.)

Participants were randomly assigned to a *long-deadline* condition (1200 ms) or a *short-deadline* condition (600 ms). If they did not respond before the deadline, a message (“Please respond faster!”) appeared (1000 ms), after which the next trial began. Incorrect responses triggered an “X” (1000 ms), after which the next trial began. Participants completed four equivalent blocks of 52 experimental trials; within-block trial order was pseudo-randomized (see Samson et al., 2010). Sixteen practice trials preceded the first block of experimental trials.

Results

Error rates. Table 1 displays error rates by condition. A 2 (Deadline) $\times$ 2 (Perspective) $\times$ 2 (Consistency) mixed ANOVA, with repeated measures on the last two factors, yielded main effects of Perspective (other>self), $F(1, 113)=43.10, p<.001, \eta_p^2=.28$, Consistency (inconsistent>consistent), $F(1, 113)=288.74, p<.001, \eta_p^2=.72$, and Deadline (short>long), $F(1,$

113)=90.36, $p<.001$, $\eta_p^2=.44$. A Perspective $\times$ Consistency interaction, $F(1, 113)=61.24$, $p<.001$, $\eta_p^2=.35$, further indicated that, as in prior studies (e.g., Samson et al., 2010; Surtees et al., 2016; Todd & Simpson, 2016), the effect of consistency was stronger on other-perspective versus self-perspective trials (egocentric intrusion > altercentric intrusion).

More important for the current research was a significant 3-way interaction, $F(1, 113)=12.34$, $p=.001$, $\eta_p^2=.10$.² To unpack this interaction, we calculated indices of egocentric intrusion (other-inconsistent errors – other-consistent errors) and altercentric intrusion (self-inconsistent errors – self-consistent errors). As shown in Table 1, time pressure increased both intrusion effects; however, the effect of deadline was considerably larger on egocentric ($M_{\text{diff}}=15.8\%$; $t[113]=6.25$, $p<.001$, Hedges' $g_s=1.16$) versus altercentric intrusion ($M_{\text{diff}}=5.6\%$; $t[113]=2.90$, $p=.004$, $g_s=0.54$).

Table 1

Error rates by perspective, consistency, and deadline condition (Experiment 1)

Deadline	Perspective and consistency					
	Other			Self		
	Consistent	Inconsistent	Egocentric intrusion	Consistent	Inconsistent	Altercentric intrusion
Long (1200 ms)	5.3 (6.3)	17.7 (12.8)	12.4 (10.9)	5.6 (7.7)	11.8 (11.0)	6.1 (8.9)
Short (600 ms)	15.3 (13.3)	43.5 (15.5)	28.1 (16.0)	15.4 (11.0)	27.1 (12.8)	11.7 (11.7)

Notes. Standard deviations are in parentheses. Egocentric intrusion = inconsistent-other errors – consistent-other errors. Altercentric intrusion = inconsistent-self errors – consistent-self errors.

PDP estimates. Recall that claims of automaticity in L1-VPT pertain specifically to altercentric-intrusion effects; thus, our PDP analyses focused on self-perspective trials only.

²There were also Deadline $\times$ Perspective, $F(1, 113)=10.38$, $p=.002$, $\eta_p^2=.08$, and Deadline $\times$ Consistency interactions, $F(1, 113)=38.77$, $p<.001$, $\eta_p^2=.26$, that are best understood in the context of the 3-way interaction.

Using equations (3) and (4) described earlier, we computed separate estimates of C and A for each participant. In cases of perfect performance ($C=1$), A is undefined; thus, we applied an adjustment commonly used in signal-detection analyses (see Snodgrass & Corwin, 1988). As expected, C was weaker in the short-deadline condition ($M=.57$, $SD=.20$) than in the long-deadline condition ($M=.80$, $SD=.16$; $t[113]=6.93$, $p<.001$, $g_s=1.29$), whereas A was comparable across conditions (short-deadline: $M=.65$, $SD=.16$; long-deadline: $M=.64$, $SD=.21$; $t<1$, $p=.72$).

Experiment 2: Social vs. Non-Social Target

Experiment 1 provided initial evidence that processes underlying altercentric-intrusion effects operate in theoretically-predicted ways. In line with prior PDP research, imposing time-pressure weakened the ability to deliberately report one's own perspective (i.e., controlled processing), but it did not affect tendencies to spontaneously calculate the avatar's perspective (i.e., automatic processing). In Experiment 2, we aimed to create a condition that would affect automatic processing of others' perspectives. Guided by prior findings that altercentric-intrusion effects are stronger for social versus non-social entities (Nielsen et al., 2015; Todd & Simpson, 2016), we varied whether the target in the L1-VPT task was human or non-human. We predicted that target-based differences in altercentric intrusion would be driven by differences in A , whereas C would remain relatively unchanged.

Method

Native English-speaking undergraduates ($N=119$) participated for course credit. Data were excluded from 8 participants (2 in the social condition, 6 in the non-social condition) with below-chance task performance. We also excluded data from 2 participants (both in the non-social condition) with negative C estimates, leaving a final sample of 109 (72 women, 37 men).

The L1-VPT task was identical to that from Experiment 1, with two exceptions. First, participants were randomly assigned to a *social* condition wherein a human avatar appeared in the room, or a *non-social* condition wherein a dual-colored (yellow/blue) stick (Surtees & Apperly, 2012; Todd & Simpson, 2016) appeared instead. In this latter condition, on *other* trials, participants verified if the number of dots on the yellow side of the stick matched or mismatched a given number; on *self* trials, they verified if the number of dots they could see matched or mismatched a given number. Second, we held the response-deadline constant at 750 ms.

Results

Error rates. Table 2 displays error rates by condition. A 2 (Target) $\times$ 2 (Perspective) $\times$ 2 (Consistency) mixed ANOVA, with repeated measures on the last two factors, yielded main effects of Perspective (other>self), $F(1, 107)=24.85, p<.001, \eta_p^2=.19$, Consistency (inconsistent>consistent), $F(1, 107)=235.32, p<.001, \eta_p^2=.69$, and Target (non-social>social), $F(1, 107)=4.13, p=.045, \eta_p^2=.04$, and a Perspective $\times$ Consistency interaction (egocentric intrusion>altercentric intrusion), $F(1, 107)=64.90, p<.001, \eta_p^2=.38$.

More important for the current work was a significant 3-way interaction, $F(1, 107)=6.58, p=.012, \eta_p^2=.06$.³ To unpack this interaction, we again calculated indices of egocentric and altercentric intrusion. As shown in Table 2, altercentric intrusion was stronger for the social versus the non-social target ($M_{\text{diff}}=8.7\%$; $t[107]=3.84, p<.001, g_s=0.73$), whereas egocentric intrusion was comparable across targets ($M_{\text{diff}}=0.3\%$; $t<1, p=.93$), which replicates prior findings suggesting that altercentric (but not egocentric) intrusion is stronger for social versus non-social entities (Nielsen et al., 2015; Todd & Simpson, 2016; but see Santiesteban et al., 2014).

Table 2

³There was also a Target $\times$ Consistency interaction, $F(1, 107)=4.82, p=.030, \eta_p^2=.04$, that is best understood in the context of the 3-way interaction.

Error rates by perspective, consistency, and target condition (Experiment 2)

Target	Perspective and consistency					
	Other			Self		
	Consistent	Inconsistent	Egocentric intrusion	Consistent	Inconsistent	Altercentric intrusion
Social (avatar)	9.9 (12.2)	32.2 (17.7)	22.3 (15.8)	10.5 (8.6)	23.8 (11.2)	13.3 (10.8)
Non-social (stick)	15.2 (11.8)	37.3 (17.3)	22.0 (14.6)	17.9 (13.8)	22.5 (13.6)	4.6 (12.7)

Notes. Standard deviations are in parentheses. Egocentric intrusion = inconsistent-other errors – consistent-other errors. Altercentric intrusion = inconsistent-self errors – consistent-self errors.

PDP estimates. We next computed estimates of C and A for each participant. As expected, A was greater for the social ($M=.69$, $SD=.17$) versus the non-social target ($M=.57$, $SD=.16$; $t[107]=3.79$, $p<.001$, $g_s=0.72$), whereas C did not differ significantly across targets (social: $M=.65$, $SD=.16$; non-social: $M=.59$, $SD=.24$; $t[107]=1.39$, $p=.167$, $g_s=0.26$).

Discussion

Two experiments examined processes underlying L1-VPT in adults. Prior research has generally interpreted altercentric-intrusion effects in the L1-VPT task as reflecting the relatively automatic calculation of others' visual perspectives (e.g., Baker et al., 2016; Bukowski et al., 2015; Furlanetto et al., 2016; Qureshi et al., 2010; Ramsey et al., 2013; Samson et al., 2010; but see Cole et al., 2015, 2016; Santiesteban et al., 2014). Eschewing the implied "process-purity" assumption of task-dissociation approaches (Jacoby, 1991), we used an alternative approach that quantifies the unique contributions of automatic and controlled processes on altercentric-intrusion effects. In Experiment 1, imposing a fast response-deadline reduced controlled processing, but it left automatic processing of the avatar's perspective unchanged. In Experiment 2, automatic processing of the target's perspective was stronger if the target was a human avatar

rather than a non-human entity, whereas controlled processing was not significantly different as a function of the specific target. Critically, this double-dissociation by theoretically-relevant manipulations validates the assumption that automatic and controlled processes are independent and specifies different conditions under which these distinct processes operate.

Our findings have multiple implications for L1-VPT and the broader perspective-taking literature. Central among these contributions is that the process-dissociation approach used here casts altercentric-intrusion effects in a new light. Consider, for example, results from Experiment 1 indicating that time-pressure significantly increased both egocentric *and* altercentric intrusion. These results are conceptually similar to those reported by Qureshi et al. (2010), who found that performing a secondary, resource-consuming task alongside the L1-VPT task also increased both types of intrusion. A standard, task-dissociation interpretation of altercentric-intrusion effects, which takes the effect itself as evidence of spontaneous perspective taking, would suggest that experiencing cognitive load (e.g., in the form of time-pressure or a secondary task) *strengthens* automatic processing of others' visual perspectives. A process-dissociation approach, however, affords a very different interpretation of these same findings. By disentangling the unique contributions of automatic and controlled processes on task performance, PDP analyses revealed that automatic processing of the avatar's perspective was unaffected by time-pressure; rather, time-pressure *decreased* controlled processing, and it was this reduction in controlled processing that produced the observed pattern of increased altercentric-intrusion effects in task performance.

Adopting a process-dissociation approach could also be useful for clarifying other findings in the literature. For example, Surtees and Apperly (2012) found that altercentric-intrusion effects are stronger in younger children (6-year-olds) than in older children (10-year-olds) and adults. Because executive function continues to develop throughout childhood and

adolescence (Zelazo & Carlson, 2012) and given established links between executive function and controlled-processing estimates in the PDP (Ito et al., 2015), future work should explore whether Surtees and Apperly's findings might reflect age differences in controlled processing rather than differences in automatic processing of the target's perspective.

The process-dissociation approach could also be useful for clarifying null effects reported in prior research. For example, Schwarzkopf et al. (2014) reported comparable altercentric-intrusion effects for adults with high-functioning autism (HFA) and healthy adults, which they interpreted as equivalent spontaneous L1-VPT. Given established links between autism spectrum disorders and impaired executive function (Hill, 2004), future work should explore whether Schwarzkopf et al.'s null findings indeed reflect equivalent automatic processing of the target's perspective between HFA and healthy adults or whether there are group differences in automatic processing that are masked by differences in controlled processing in the opposite direction.

We used the process-dissociation procedure (Jacoby, 1991) to quantify the extent of automatic and controlled processing during level-1 visual perspective taking in adults. In doing so, our experiments illustrate how a class of methodological tools can be implemented to advance psychological theory (Greenwald, 2012). We hope this approach will prove useful in further advancing scientific understanding of the processes underpinning perspective taking.

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