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Do you see what I see? A meta-analysis of the Dot Perspective Task

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Abstract

Recent research has found evidence for *implicit* theory of mind, suggesting that humans quickly and involuntarily compute the mental states of others. One highly influential task within this literature, known as the Dot Perspective Task (DPT), purports to demonstrate implicit visual-perspective taking within adult subjects. However, some studies, consisting of variations of the DPT, have challenged these findings suggesting that the DPT does not demonstrate genuine perspective taking. Instead, they argue that these results are reflective of simple attentional cueing. Additionally, some researchers have argued that the DPT is sensitive to unintended attentional and intentional factors. We report the preliminary findings of an on-ongoing meta-analysis which analyzes participant-level data from 23 experiments and 1381 individual subjects. We find evidence for both directional cueing and implicit perspective taking within the DPT, although the effects of directional cueing are significantly larger. Additionally, we find that the effects of perspective taking are sensitive to attentional and intentional factors. These results cast doubt upon much of the evidence which has been taken to demonstrate implicit theory of mind. At the same time, they suggest that future work may utilize a carefully controlled version of the DPT in order to measure genuine implicit theory of mind more accurately.

Keywords: Theory of Mind, Automaticity, Submentalizing, Dot Perspective Task, Implicit, Visual Perspective Taking

Theory of mind (‘or ‘mentalizing’) capacities allow us to enjoy rich and complex social lives. We mentalize when we plan surprises, infer goals, keep secrets, or reason about differing beliefs. Given the pervasive presence of mentalizing in human interactions, researchers have suggested that theory of mind (ToM) representations may be computed in a highly efficient way, emerge early in ontogeny, and operate mandatorily (Southgate & Vernetti, 2014; Kovács, Téglás, & Endress, 2010). In other words, researchers have sought evidence for an *implicit* ToM system.

To investigate this hypothesis, researchers have designed paradigms which test for ToM while ensuring that subjects are *unable* or *unlikely* to employ *explicit* ToM reasoning. One such strategy has utilized eye-tracking and interactive helping experiments with children before the age of four, while they are still unable to pass explicit false-belief tasks; see Barone, Corradi, and Gomila (2019) for a review. Another strategy has focused on automatic visual perspective taking in adults by employing paradigms in which explicit mentalizing is task-irrelevant. The most popular of these visual perspective taking tasks, known as the dot perspective task (DPT), is widely interpreted as providing evidence that adults automatically compute the visual perspectives of others (Samson, Apperly, Braithwaite, Andrews, & Bodley-Scott, 2010). Based on these findings, researchers have begun to use this task as a tool to investigate ToM within clinical populations and in conjunction with behavioral endocrinology (Drayton, Santos, & Baskin-Sommers, 2018; Yue, Jiang, Yue, & Huang, 2017). However, despite the DPT’s popularity within psychological research, there are outstanding questions regarding the task’s external validity in capturing theory of mind.

The Dot Perspective Task

Originally conceived by Samson et al. (2010), the DPT requires subjects to make speeded yes/no responses concerning the number of dots in a scene that are visible to either themselves or to a target agent. The scene consists of a lateral view of a room, an avatar (or other target stimulus) in the center of the room, and 0-3 red dots on one or two walls (see Figure 1). The avatar appears in profile, facing either the left or right wall. Thus, the avatar’s visual field is always a subset of the whole room, while the room is visible in its entirety to the subject. Crucially, if all of the dots within the scene are located on the wall which the avatar faces, then the subject’s and avatar’s visual perspectives are *consistent*. However, if one or more dots appear on the wall *behind* the avatar, then the avatar’s visual perspective is *inconsistent* with the subject’s. In each trial, subjects are shown a perspective cue (SHE/HE or YOU) and number cue (0-3), followed by either a consistent or inconsistent scene. If the number cue matches the number of dots that are visible to the cued perspective, then the subject should answer ‘Yes’, and if not, ‘No’.

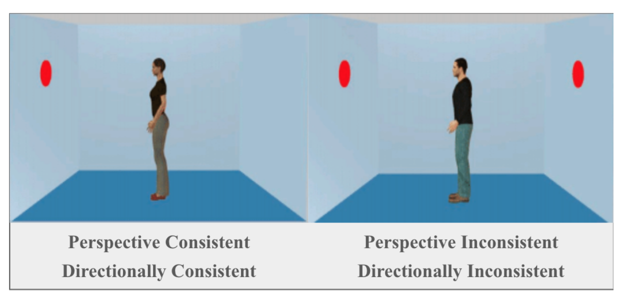

Figure 1: Sample avatar stimuli as originally used by (Samson et al., 2010) where directional consistency and perspective consistency are not dissociated.

Samson et al. (2010) found that in ‘self’ trials (i.e., perspective cue = YOU) subjects were slower and less accurate when responding to scenes in which the agent saw an

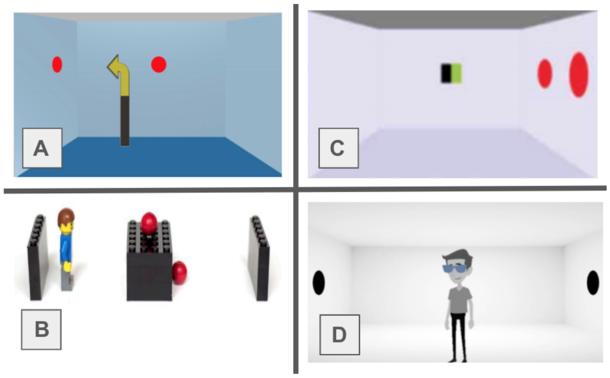

Figure 2: **A**: Directionally Inconsistent & No Perspective (Santiesteban et al., 2014), **B**: Directionally Consistent & Perspective Inconsistent (Santiesteban et al., 2014), **C**: No Directionality & No Perspective (Nielsen et al., 2015), **D**: Directionally Inconsistent & Perspective Inconsistent (Marshall et al., 2018)

inconsistent (rather than consistent) number of dots. It is suggested that this result provides evidence for implicit mentalizing, wherein the participants automatically compute the avatar's perspective and must suppress this perspective during inconsistent 'self' trials. Although this consistency effect has been widely replicated, its theoretical upshots remain debated. Some researchers argue for a more deflationary explanation of the DPT involving directional or experimental cues, and domain general processing.

The Current Debate

Is this Truly ToM?

A challenge to the 'mentalizing' interpretation of the DPT has come by way of a 'submentalizing' account. According to the 'submentalizing' explanation of the DPT, the consistency effect is not due to the ascription of a visual perspective. Rather, it arises from other domain-general 'submentalizing' processes. Although these results align with the expected effects of mentalizing, they do not involve the computation of mental states (Heyes, 2014). For example, Heyes and colleagues argue that the consistency effect found in the Samson DPT results from attentional cueing which is caused by the directional features of the avatar. When the avatar 'points' to the complete set of dots which are relevant to the task, there is a performance advantage. In the original Samson task, 'perspective consistency' (consistency between the subject's and avatar's visual perspectives) and 'directional consistency' (consistency between the subject's visual perspective, and the number of dots which are pointed to by the avatar) cannot be dissociated (see Figure 1).

Subsequent research has sought to settle the mentalizing/submentalizing dispute by introducing novel variations of the DPT which dissociate directional and perspective consistency (Figure 2). There have been three major approaches. First, researchers have replicated the DPT using an arrow (in place of an avatar) which has directional features, but is not an appropriate candidate for visual perspective attribution (Santiesteban et al., 2014; Conway, Lee, Ojaghi, Catmur, & Bird, 2017; Wilson, Soranzo, & Bertamini, 2017; Nielsen et al., 2015; Gardner, Hull, Taylor, & Edmonds, 2018; Marshall et al., 2018) . Second, researchers have obstructed the avatar's visual access to the dots via 'occluders' such that perspective attribution is hindered, but directional consistency is not (Baker, Levin, & Saylor, 2016; Cole, Atkinson, Le, & Smith, 2016; Langton, 2018; O'Grady, Scott-Phillips, Lavelle, & Smith, 2020). Finally, researchers have depicted avatars wearing opaque goggles or blindfolds in order to make the avatar's visual perspective irrelevant without altering directional features (Furlanetto, Becchio, Samson, & Apperly, 2016; Wilson et al., 2017; Conway et al., 2017; Marshall et al., 2018).

Despite extensive research, there is no clear consensus on the extent to which perspective taking and directional cueing underlie the consistency effect. In some cases, promising studies utilizing opaque and transparent goggles, such as that by Furlanetto et al. (2016), have partially or fully failed to replicate (Wilson et al., 2017; Conway et al., 2017; Marshall et al., 2018). In other cases, there have been severe theoretical hurdles to interpretation (for the limitations of 'arrow' experiments, see Cole et al., 2016; O'Grady et al., 2020). This body of work is especially difficult to interpret qualitatively because the manipulation of directional and perspective consistency has often been confounded with variations in the experimental design, task instructions, and stimuli. By re-coding participant-and-condition-level behavioral data according to each of these factors, the present meta-analysis can dissociate the effects of directional and perspective consistency.

Is This Truly Automatic?

In addition to questioning whether genuine ToM is at play in the DPT, researchers have questioned the extent to which the underlying process is truly automatic. This question has been discussed in terms of 'implicitness', 'spontaneity', and 'automaticity'. Although some researchers have been clear in defining these terms, in other cases, they have been used interchangeably. For the sake of clarity, we will use 'implicit' as a broad term which refers to processes which occur without explicit and conscious effort. We take automatic processes to be those which are stimulus-driven, happen reflexively, and cannot be self-inhibited (Back & Apperly, 2010); see Melnikoff and Bargh (2018) for an opposing view. In contrast, spontaneous processes, while fast and unconscious, may be dependent upon such factors as attention or intention (Bukowski, Hietanen, & Samson, 2015; O'Grady et al., 2020).

Given these definitions, it would be very difficult to oppose the implicitness of the DPT consistency effect (as, given the task-irrelevance and time constraints within critical 'self' trials, it is extremely unlikely that the consistency effect results from an effortful process). The present analyses therefore concern whether the process underlying the DPT is automatic, or instead merely spontaneous. Because automatic and spontaneous processes are differentiated by their sensitivity to attention and intention, we can make progress on this question by quantitatively investigating whether the DPT consistency effect is dependent upon attentional or intentional factors.

Researchers have sought to investigate automaticity within the DPT through a collection of changes to the experimental design, task instructions, and stimuli used. In some experiments, 'self' and 'other' trials were intermixed within experimental blocks. It has been suggested that this self/other mixing may elicit carryover effects, whereby participants are more likely to be distracted by the avatar's perspective when they are explicitly concerned with that perspective in preceding trials (Ferguson, Apperly, & Cane, 2017; Conway et al., 2017). Put simply, perspective-taking is not *truly* task-irrelevant in any experimental block which includes 'other' trials. The mixing of self and other trials therefore influences the attention and intention of participants, making the avatar's perspective more relevant. A process which is elicited only when such cues are present should not be considered automatic. A range of other design choices are likely to have a similar impact upon the the attention and intention of the participants within each experiment. In some experiments, for example, the task instructions explicitly included reference to perspective-taking, while others did not. In other cases, visual cues used within the experiment were either social words (such as 'you' or 'he') or nonsocial words (such as 'total' or 'block'). In the present meta-analysis, the behavioral data from each included paper have been classified according to the 'perspective-taking cues' in that study. Our analyses will seek to determine the relevance of these factors to the observed consistency effect.

Methodological Validation

In addition to the theoretical debate surrounding the DPT, there is a practical concern over the sensitivity of error rate and reaction time (RT) data in capturing implicit mentalizing effects. In particular, many studies report minimal errors across conditions and thus do not report significant effects using error rate data (Conway et al., 2017; O'Grady et al., 2020; Schurz et al., 2015). In contrast, others have found significant mentalizing effects on error rate (Samson et al., 2010; Marshall et al., 2018; Santiesteban et al., 2014; Furlanetto et al., 2016). One hypothesis for these varying results is that small sample sizes are not able to reliably capture error rate effects. By taking a meta-analytic approach, our analyses are uniquely powered to investigate the sensitivity of these measures.

The Present Meta-Analysis

The present meta-analysis combines participant-by-condition level data from DPT studies and codes them according to the directional and perspective consistency in each experimental condition. Other variables of interest include experimental design, stimuli, and task instructions used in each experiment. These variables are then used as predictors of error rate and response time in a series of linear mixed-effects models. This approach allows us to quantitatively determine the relative strength and robustness of directional and perspective consistency effects, and how these effects are influenced by a range of contrasting experimental conditions.

These analyses will not only bare on the plausibility of the mentalizing and submentalizing hypotheses, but also the extent to which the observed effect should be considered automatic. A key question in this debate is whether perspective consistency adds predictive power *beyond* directional consistency. If so, then the DPT results cannot be due to simple directional cueing. Further, investigating how attentional and intentional manipulations interact with the effects of perspective consistency can shed light on whether the underlying process should be considered fully automatic or only spontaneous. Finally, the present meta-analysis sheds new light on the relative sensitivity of error rate and response time when used as measures of performance in an implicit ToM task.

Method

Our meta-analysis currently consists of 11 papers comprised of 23 experiments published between 2010 and 2020. These papers include 264 different experimental conditions and 1381 individual subjects. See Appendix 1 for a list of papers.

Study Selection

Studies were included if they 1) were replications or variations of the DPT, 2) tested neurotypical adult subjects, and 3) utilized error rate and/or response time as dependent measures. In cases where only some of the conditions within an experiment satisfied these criteria, only the satisfactory conditions were included. In order to find eligible studies, we first conducted a literature search using connectedpapers.com, google scholar, and recommendations from colleagues, and searched within all papers which cited Samson et al. (2010) (the paper which introduced the DPT). Papers were filtered according to keywords which are likely to appear in DPT literature, and were screened for inclusion according to the aforementioned criteria. We have identified 50 peer-reviewed publications which utilize the DPT in their own experimental work. The present preliminary analyses include data from 11 publications, from which raw subject data have been received, categorized, and incorporated into our database. Data collection from the other publications remains ongoing.

Data Aggregation

Raw behavioral data were solicited from the corresponding authors of each paper or taken from publicly available supplementary materials. For studies in which non-behavioral data were collected (such as neuroimaging data) only behavioral data (error rates and response times) were requested. For consistency, all data were transformed into participant-by-condition averages for both reaction time data and/or error rate data. Each data-set was cleaned according to the exclusion criteria outlined in the original paper. Finally, all 'no' response trials (in which the correct response was 'no') were removed. Such 'no' trials may create uneven task demands across consistent and inconsistent trials, leading most studies to exclude these trials from analyses (Samson et al., 2010; Santiesteban et al., 2014).

Coding

Each experimental condition was coded according to variables of theoretical interest, such as directional consistency and perspective consistency. This allows for the potential to dissociate these oft-confounded variables. Both directional consistency and perspective consistency have three levels, consistent, inconsistent, and no direction/perspective. In perspective-consistent and perspective-inconsistent conditions, the number of dots visible to the subject is either consistent or inconsistent with the number of dots which are visible to an avatar, or similar animate agent. In no-perspective conditions, there is no animate agent depicted within the scene (i.e., there is no object within the scene to which one could appropriately attribute a visual perspective).

Similarly, in directionally-consistent and directionally-inconsistent trials, the number of dots visible to the subject is either consistent or inconsistent with the number of dots which are oriented to by a directional stimulus (e.g., an avatar or arrow). In no-directionality conditions, no directional cue is depicted within the scene (e.g. the avatar is replaced by a rectangular block). Directional and perspective consistency therefore depend both upon the type of agent/stimulus, as well as the distribution of dots relative to this stimulus. To illustrate: trials which utilized arrows could be either directionally-consistent or directionally-inconsistent, but were always no-perspective trials. This is because arrows have directionality but do not have a visual perspective.

Experimental conditions were also classified according to task instructions, such as which perspective, if any, participants were asked to attend to. An 'explicitly-tracking-other-perspective' variable was coded to classify papers according to whether 'self' and 'other' trials were intermixed within experimental blocks, thereby making both self and other perspectives explicitly relevant to the task. Similarly, each experiment was classified according to the type of word cue utilized (social or nonsocial) and whether participants were explicitly asked to track their *own* perspectives. Re-classifying the data according to these theoretically motivated variables allows for cross-study analyses of automaticity.

Finally, conditions were classified according to unique paper id, unique participant id, timeout procedure, device utilized within the task (mouse or keyboard), and stimulus variant (for conceptually analogous, but non-identical stimuli). While unlikely to bare on our theoretical questions, these variables could prove useful to others interested in using the DPT. Upon publication, we will make our dataframe publicly available.

Analysis Approach

To investigate our hypotheses, we used the *lme4* package in R to compare linear mixed-effects models using reaction time and error rate as dependent variables (Kuznetsova & Brockhoff, 2016). The significance of an effect of interest was determined by comparing a model that included the key term to a model that did not, while holding fixed all other factors that were not under investigation. The significance of the effects were computed using the *anova* function in R for model comparison; here, we report the associated chi-square and p-values.

Results

Theory of Mind Analyses

To investigate whether the results are driven by submentalizing, we conducted an analysis of the relationship between perspective consistency and directional consistency. We first analyzed only 'self' trials to isolate those trials in which others' perspectives can be said to influence one's own. This is widely taken as the key Theory of Mind test in the DPT. These models also estimated random slopes and intercepts for each study within a paper, as well as random intercepts for each subject and stimulus/agent.

In support of submentalizing accounts, we found a large effect of directional consistency on reaction time, controlling for perspective consistency ($\chi^2 = 15.11$, $p < .001$). However, in support of mentalizing accounts, we found a smaller but still significant effect of perspective consistency, even when controlling for directional consistency ($\chi^2 = 6.23$, $p = .044$). In both cases, consistent trials were faster than inconsistent trials.

Turning to participants' error rates, the effects of directional and perspective consistency were not cleanly dissociable. While neither had an effect controlling for the other, directional consistency did predict reductions in error on its own ($\chi^2 = 18.09$, $p < .001$), as did perspective consistency ($\chi^2 = 19.62$, $p < .001$).

These results suggest that both perspective consistency and directional consistency can influence participant responses, with reaction time serving as a generally more sensitive measure. Thus, studies in which manipulations of perspective and directional consistency are not carefully disentangled, and especially those which rely upon error rates, should cautiously interpret the theoretical implications of their findings.

Automaticity vs. Spontaneity Analyses

We next investigated the extent to which the perspective consistency effect could be driven by attention or intention, by looking for an interaction between perspective consistency and whether the condition involved explicitly tracking the avatar's perspective. This allowed us to ask whether the effect of the avatar's perspective is dependent upon a task design which makes that perspective salient. We again restricted our analyses to only 'self' trials.

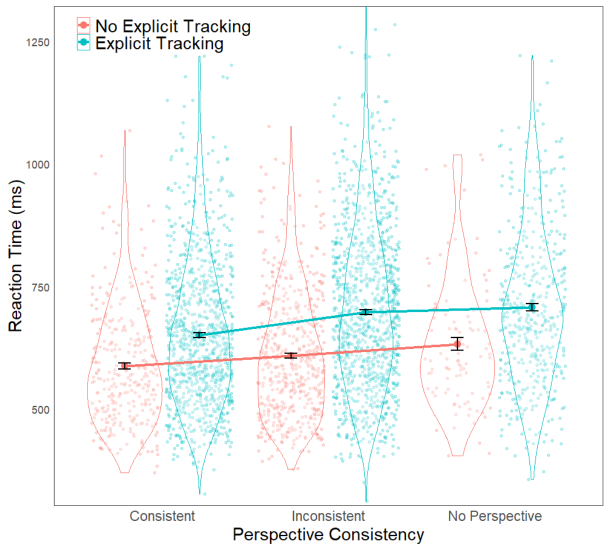

Figure 3: Mean reaction time as a function of explicit tracking and perspective consistency. Points depict participant-level means; violin plots depict group-level distributions; and error bars depict group-level means +/-1 standard error.

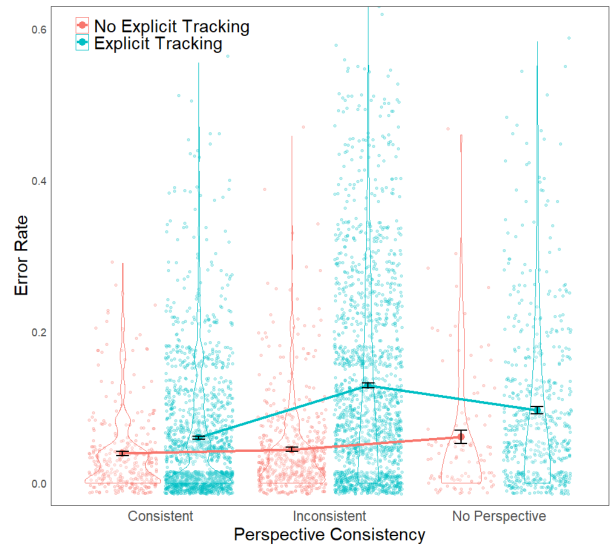

Figure 4: Mean error rate as a function of explicit tracking and perspective consistency. Points depict participant-level means; violin plots depict group-level distributions; and error bars depict group-level means +/-1 standard error.

For reaction time, we found that perspective consistency interacted significantly with whether the task involved explicit tracking (controlling for directional consistency), $\chi^2 = 11.47$, $p = .003$. This interaction can be attributed to a significantly larger effect of perspective consistency when the task involved explicitly tracking the avatar's perspective (vs. when it did not), see Fig. 3. A similar interaction between perspective consistency and explicit 'other perspective' tracking was apparent in participants' error rates (controlling for directional consistency), $\chi^2 = 18.02$, $p < .001$, see Fig. 4. This interaction suggests that the perspective consistency effect is strongly influenced by attentional cues and thus is likely largely accounted for by spontaneous rather than automatic Theory of Mind processing.

However, the effect of perspective consistency remained significant when participants were not explicitly instructed to track others' perspectives, even when analyzing only directionally consistent trials and only trials in which an animate agent was present (i.e. no arrows or rectangles). In these trials, there was a significant effect of perspective consistency on reaction time ($\chi^2 = 16.10$, $p < 0.001$) and error rate ($\chi^2 = 8.14$, $p = 0.004$). So, although the effect of perspective consistency is significantly influenced by attentional and intentional factors, the present analyses cannot establish that the effect is wholly dependent upon these factors.

Discussion

The results of this meta-analysis illustrate that both directional and perspective consistency significantly influence responses in the Dot Perspective Task. These findings show that the effect of perspective consistency cannot be explained away by appealing to directional consistency as a confounding variable. As such, our findings do not support the submentalizing hypothesis, at least insofar as it argues the effects in the DPT are fully explained by directional cueing. However, while our analyses find a significant effect of perspective consistency, this effect accounts for a smaller amount of variance than does directional consistency. This demonstrates that DPT results are largely predicted by directional cues. So, although the DPT is not solely dependent upon the influence of directional cueing, our analyses support the conclusion that directional cueing accounts for a large portion of consistency effects found within implementations of the DPT.

These findings have several implications for the future of the DPT. First, they suggest that the DPT is genuinely 'onto something,' in that consistency effects found within the task are at least partially responsive to the visual perspectives of the avatar. However, because of the comparatively large effect of directionality, there is reason for caution in using the DPT as a tool for the investigation of ToM, for example, within clinical populations. After all, the consistency effect observed within the task is not solely (or even primarily) responsive to the perspective of the avatar. Nevertheless, when cleverly designed experiments disentangle directional and perspective consistency while controlling for attentional cues, these revised versions of the DPT may indeed demonstrate the implicit calculation of others' perspectives.

In addition, our analyses were able to dissociate directional and perspective consistency within response time data, but not error rate data. This suggest that response time serves as a more sensitive metric to perspective and directional consistency manipulations than does error rate. Future research should investigate the best experimental designs for dissociating these variables.

Finally, our analyses demonstrated a significant interaction between perspective consistency and the explicit relevance of others' perspectives, suggesting that the results of the DPT are highly sensitive to changes in participants' attention and intentions. These findings support the hypothesis that the DPT is mostly capturing a spontaneous process which occurs as external cues make tracking others' perspectives relevant. This builds upon work from Ferguson et al. (2017) and O'Grady et al. (2020) who found that perspective consistency effects were sensitive to manipulations of task design or instructions.

While the analyses reported thus far have been limited to those that most directly inform the submentalizing and automaticity debates, the collection of data sets we are building will allow for a wide range of additional analyses including estimating the effect of the perceived animacy of the avatar or central stimulus, differences in task instruction, differences in exclusion criteria, and a variety of other variables. Our future analyses will investigate these variables while adding more DPT data sets to this collection.

Appendix 1: Papers Included

Capozzi, Cavallo, Furlanetto, and Becchio (2014); Ferguson et al. (2017); Ferguson, Brunsdon, and Bradford (2018); Furlanetto et al. (2016); Gardner et al. (2018); O'Grady et al. (2020); Qureshi, Apperly, and Samson (2010); Santiesteban et al. (2014); Simpson and Todd (2017); Todd and Simpson (2016); Todd, Cameron, and Simpson (2017)

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