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Brief article

The role of control functions in mentalizing: Dual-task studies of Theory of Mind and executive function ☆

Rebecca Bull *, Louise H. Phillips, Claire A. Conway

School of Psychology, William Guild Building, University of Aberdeen, Aberdeen AB24 2UB, UK

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Abstract

Conflicting evidence has arisen from correlational studies regarding the role of executive control functions in Theory of Mind. The current study used dual-task manipulations of executive functions (inhibition, updating and switching) to investigate the role of these control functions in mental state and non-mental state tasks. The 'Eyes' pictorial test of Theory of Mind showed specific dual-task costs when concurrently performed with an inhibitory secondary task. In contrast, interference effects on a verbal 'Stories' task were general, occurring on both mental state and non-mental state tasks, and across all types of executive function. These findings from healthy functioning adults should help to guide decisions about appropriate methods of assessing ToM in clinical populations, and interpreting deficits in performance in such tasks in the context of more general cognitive dysfunction.

Keywords: Theory of Mind; Executive functioning; Dual-task

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* Corresponding author. Tel.: +44 1224 272235.
E-mail address: r.bull@abdn.ac.uk (R. Bull).

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1. Introduction

Theory of Mind (ToM) is the ability to interpret another's mental states – encompassing desires, beliefs, and intentions – which may conflict with the observer's own knowledge or with reality. Effective ToM skills are important for normal social functioning (Baron-Cohen, 1995) because they underlie the understanding of others' behaviour. An important set of cognitive processes supporting ToM skills are executive functions (EFs, see Perner & Lang, 1999 for a review), which include cognitive control mechanisms such as attentional flexibility, inhibition of prepotent information, and updating information in working memory (e.g., Miyake et al., 2000). Early conceptions of ToM emphasised the modular, domain-specific social processing involved, excluding the involvement of domain-general processes such as EFs, at least in adults (Baron-Cohen, 1995; Fodor, 1992; Leslie, 1994). More recent literature has argued that social understanding is likely to involve both modular processes and domain-general processes such as EFs (e.g., Leslie, Friedman, & German, 2004; Leslie, German, & Pollizi, 2005).

Previous studies investigating the link between ToM and EFs have analysed correlations between the two types of task, or patterns of impairment in populations with poor social functioning. Children with autism or Aspergers Syndrome have difficulty interpreting cues to mental state (e.g., Baron-Cohen, 1995; Happe, 1994), whilst being unimpaired on matched tasks with similar EF demands but with no requirement to understand mental states (e.g., Charman & Baron-Cohen, 1995; Leslie & Thaiss, 1992). Studies with older adults reveal that whilst there are well-replicated age-related declines in EFs (e.g., MacPherson, Phillips, & Della Sala, 2002; Wecker, Kramer, Wisniewski, Delis, & Kaplan, 2000), the effects of age on ToM tasks are unreliable: some studies indicate decline in ToM (e.g., Maylor, Moulson, Muncer, & Taylor, 2002), others stability (e.g., MacPherson et al., 2002) or advantage (Happe, Winner, & Brownell, 1998) with age. Maylor et al. (2002) showed that despite age-related decline in both ToM and EFs in the same sample, there was no relationship between the two impairments. Also, patient studies show spared ToM skills in the presence of EF impairments (Bird, Castelli, Malik, Frith, & Husain, 2004), poor mental-state reasoning in the presence of spared EF skills (Fine, Lumsden, & Blair, 2001; Lough, Gregory, & Hodges, 2001) or preserved ToM impairments when EF skills were covaried (Rowe, Bullock, Polkey, & Morris, 2001). These findings indicate independence of ToM and EF skills. However, as noted by German and Hehman (2006), these studies may underestimate fractionation within executive processes, so finding an association between ToM and EF may depend on the measures chosen.

A number of studies have challenged the modular view of ToM, based on evidence of relationships between ToM and EF performance in typically developing and autistic children (e.g., Carlson, Moses, & Brenton, 2002; Hughes, 1998; Hughes, Russell, & Robbins, 1994; Ozonoff, Pennington, & Rogers, 1991; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Zelazo, Jacques, Burack, & Frye, 2002). German and Hehman (2006) found evidence from an aging sample for common processing in ToM

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and EF tasks, with age-related declines in reasoning both about mental and non-mental states overlapping statistically with decreased inhibitory control. Incrementing the executive demands of ToM tasks increased the magnitude of age deficits (see also McKinnon & Moscovitch, 2007). Finally, lesion and neuroimaging studies indicate that the prefrontal cortex is involved in both EFs and ToM (e.g., Channon & Crawford, 2000; Fletcher et al., 1995; Sabbagh, 2004; Stone, Baron-Cohen, & Knight, 1998; Stuss, Gallup, & Alexander, 2001), suggesting that both processes may depend on a common neuroanatomical system. However, Apperly, Samson, and Humphreys (2005) note that many neuropsychological studies fail to separate belief reasoning from other processes necessary for completion of these tasks, raising doubts about strong claims regarding domain-specificity of ToM.

The current study utilises dual-task methodology with healthy adults to investigate the resource overlap between ToM tasks and EF. Using dual-task methodology, McKinnon and Moscovitch (2007) found that concurrent performance of an updating task impaired answering both first- and second-order ToM questions, with greater interference for the more complex second-order questions. However, this study did not include control non-mental state tasks, and so the specificity of the role of updating in ToM cannot be determined. Also, the role of other EFs such as inhibition and switching attention remains unexplored.

Although ToM has often been considered a unitary construct, it is likely that different methods of assessing social understanding place different demands on EFs. For example, Lough et al. (2006) found statistical overlap between EF and a ToM stories task, but not with a cartoon test of ToM. The current study examined two of the most widely used ToM tasks in adult populations. *Stories* tests of ToM (e.g., Channon & Crawford, 2000; Happe, 1994; Stone et al., 1998) assess understanding of faux pas, double bluffs, mistakes, and white lies, and typically involve considering the mental states and related behaviours of multiple characters, which might include false beliefs. In contrast, the *Mind in the Eyes Test* (Baron-Cohen, Wheelright, Hill, Raste, & Plumb, 2001) requires recognition of emotional states from pictures of eyes, and does not require coordination of multiple perspectives or the integration of mental states with behaviours.

Most studies examining the relationship between EF and ToM have used complex EF tasks that load multiple control skills. We aimed to delineate more precisely the nature of EF involvement in ToM tasks by administering separate tasks of inhibition, switching, and updating. Three issues will be investigated. First, if Eyes and Stories ToM tasks depend upon the same pool of cognitive resources as a range of EFs, there will be dual-task interference when a ToM task is performed concurrently with an EF task. Second, if interference between ToM and EF tasks is specific to interdependence between these two processes, dual-task costs should be present only when EF tasks are performed in combination with ToM items, and not in combination with non-ToM items. Third, to determine whether ToM tasks depend on specific EFs (inhibition, switching or updating) dual-task costs under separate EF secondary task conditions were examined, including a control condition which was attentionally demanding but had minimal EF load.

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2. Methods

2.1. Participants

One-hundred and fifty university undergraduate psychology students (54% female) participated in this study for course credit. Participants were aged between 16 and 31 years ($M = 19.16$ years, $SD = 2.57$). All participants had English as their first language, and normal or corrected to normal vision.

2.2. Materials

Twenty-five stimuli showing the eye region from the "Reading the Mind in the Eyes" test (Baron-Cohen et al., 2001) were shown in two conditions. In the ToM condition, four affective or mental state terms were presented, whilst in the control condition four age and gender options were presented.

The Stories task was modified from its original format of an expressive production task to a multiple choice task, making it similar to the Eyes task and more appropriate for the dual-task paradigm. Based on a large number of production responses from mental state and control (physical/mechanical) stories (see Channon & Crawford, 2000; Happe, 1994; Stone et al., 1998 for examples), the most accurate (and usually the most cited) response was selected as the correct answer. Three additional multiple-choice options were selected from the incorrect answers (some were incorrect literal interpretations, others were factually correct but did not provide the most detailed or appropriate answer, while others were totally incorrect). The multiple-choice version was administered to a new set of participants and based on the levels of accuracy and item length, 12 ToM and 12 control stories were chosen.

2.3. Design and procedure

This study used a between-subjects design due to limitations in the number of ToM stimuli available. Participants were assigned randomly to one of the five conditions. The first group completed all ToM and Control tasks under single-task conditions. The other groups completed all ToM and Control tasks in dual-task combination with one of the three EF tasks or the EF–control task. These groups also completed the appropriate EF task in single-task conditions for 3 minutes both before and after the dual-task, with an average score used for performance accuracy. The order of administration of ToM and Control tasks was counterbalanced within each condition.

2.3.1. Eyes ToM and Eyes Control

Eyes stimuli appeared in the centre of the computer screen and participants selected which of four responses best matched the thoughts and feelings (ToM), or age and gender (Control) shown by the eyes.

2.3.2. Stories ToM and Stories Control

Participants read a short passage, with a question relating to the mental state of the characters (ToM) or a physical/mechanical event (Control). Participants selected which option from four best answered the question. The story and question were presented simultaneously to reduce memory load.

2.3.3. Executive function tasks

All EF tasks had the same basic requirement to listen to a string of numbers (presented 1 number every 3 s). The *EF-inhibition* task (a variant of a 'No Go' task; Klinberg & Roland, 1997) involved participants adding 3 to each number, but withholding their answer if it totalled 8 or 15. There were 12 items requiring inhibition in each 3-min period. The *EF-switching* task was a cued unpredictable switch task (see Rende, Ramsberger, & Miyake, 2002), and involved participants adding 2 to each number, until they were auditorily cued to switch to subtracting 1 from each number. There were 12 'switch' trials in each 3-min period. The *EF-updating* task was a variant on a 1-back working memory task (Braver et al., 1997), and involved participants adding on 1 to the number they heard one previously. Finally an *EF-control* task was developed with presentation and response requirements that matched the three EF tasks but with minimal executive load. Participants had to add 5 to each presented number. The logic here was to investigate interference caused by the EF tasks over and above interference caused by the basic need to monitor and respond to a stream of stimuli.

In dual-task conditions the EF task began at the same time as the first ToM stimulus and lasted for the duration of the ToM task. The dependant variable for all tasks was the proportion of correct responses.

3. Results

Five participants were excluded (2 each from the EF-switching and EF-control groups and 1 from the EF-updating group) as their performance on one or more tasks was more than three standard deviations from the mean. A between-groups analysis confirmed single-task accuracy was equivalent across all four EF tasks, $F(3, 111) < 1$.

For each ToM and Control task, analysis compared the effects of single-task performance against the four different dual-task conditions. All results are shown in Fig. 1. A between-subjects analysis of variance (ANOVA) indicated that for the *Eyes ToM* task there was a significant effect of secondary task condition, $F(4, 140) = 2.94$, $p < 0.05$, $\eta_p^2 = 0.08$. Post hoc tests (Tukey's HSD) revealed that performance on the single Eyes ToM task was significantly more accurate than when Eyes ToM was performed under dual-task conditions with EF-inhibition ($p < 0.05$). Accuracy on Eyes ToM under the remaining dual-task conditions was not significantly different from single-task performance. The dual-task conditions did not significantly differ from each other. An ANOVA examining accuracy on the *Eyes Control* task revealed no effect of task condition, $F(4, 140) < 1$, $\eta_p^2 = 0.02$, indicating no significant dual-task costs.

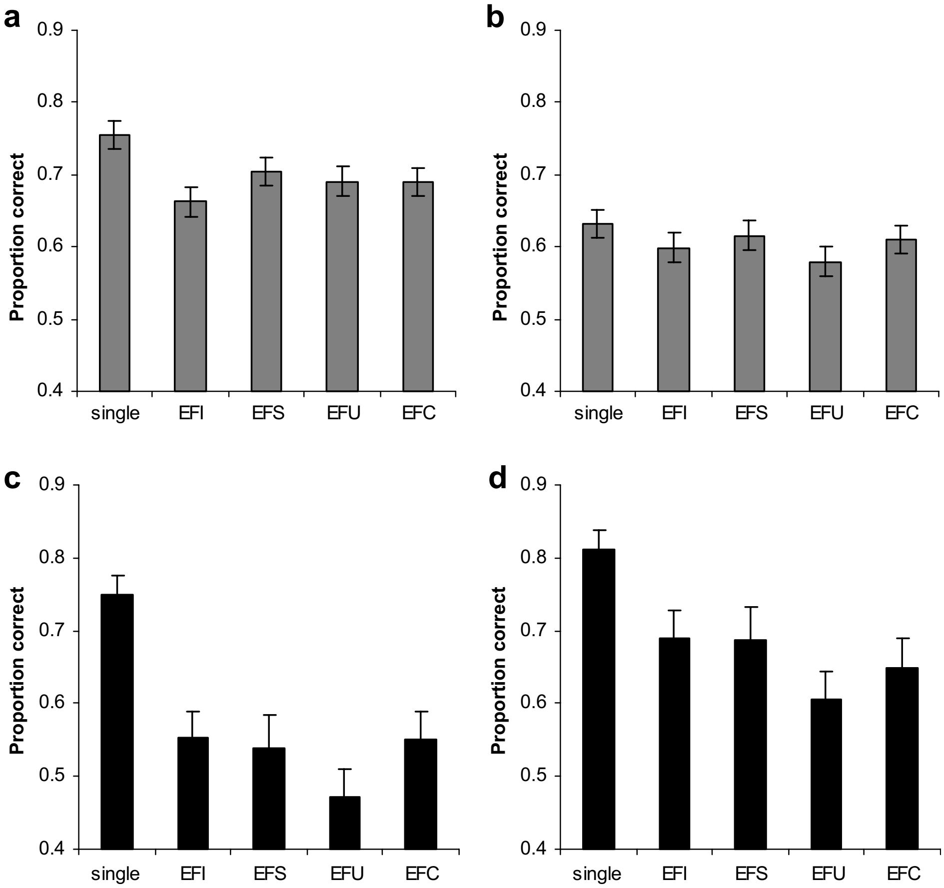

Fig. 1. Proportion correct on (a) Eyes ToM, (b) Eyes Control, (c) Stories ToM and (d) Stories Control under single and dual-task conditions (bars show standard error). EFI, inhibition; EFS, switching; EFU, updating; EFC, control.

Between subjects ANOVAs revealed a significant effect of dual-task condition for *Stories ToM*, $F(4, 140) = 7.65$, $p < 0.001$, $\eta_p^2 = 0.18$, and *Stories Control* tasks, $F(4, 140) = 6.36$, $p < 0.001$, $\eta_p^2 = 0.15$. Post hoc analysis revealed that for both ToM and Control Stories performance on all dual-task combinations was significantly less accurate than single-task performance, with none of the dual-task conditions differing significantly from one another (for Stories ToM all p's < 0.01; for Stories Control all p's < 0.05).

4. Discussion

Both Stories ToM and Stories Control were significantly disrupted under dual-task conditions, suggesting an overlap of general attentional resources rather than a specific overlap between ToM and individual EFs. All EF tasks (including EF-control) produced interference on both the ToM and control versions of the Stories task. It can be seen from Fig. 1 that the magnitude of dual-task interference is considerably higher for the Stories compared to the Eyes task. Clearly, this may be due to the complex nature of mental state reasoning in the Stories task, including comparison of multiple mental states or consideration of beliefs and subsequent emotions or actions. However, this task consists of linguistically complex narratives and the parallel drop in performance on the control Stories task suggests that dual-task interference may reflect these high incidental demands rather than mental-state reasoning per se. Associations previously found between performance on EF and Stories tasks may not be due to specific overlap of EF and ToM skills, but to more general sharing of attentional skills. Supporting this, Lough et al. (2006) found that mental state and non-mental state tasks had similar relationships to EF skills, suggesting that the overlapping variance is due to general processing demands, rather than mental state demands of ToM tasks (see also, Apperly, Samson, Chiavarino, & Humphreys, 2004; German & Hehman, 2006).

In the Eyes ToM dual-task decrements were only apparent in the inhibition condition whereas Control Eyes performance did not deteriorate significantly under any dual-task condition. This suggests that interference between ToM Eyes and EF-inhibition is specifically due to involvement of inhibitory processes in mentalising, rather than general attentional demands. Inhibition may be required if participants produce a spontaneous first impression of the mental state seen in the eyes, which they subsequently have to inhibit in order to select the closest fitting response option. To examine this, a subsequent experimental manipulation was conducted where participants ($N = 55$) viewed the four response options in the Eyes ToM and Eyes Control tasks before seeing the eye region to determine whether this would reduce the need for inhibition of a spontaneously produced response. The results replicated current findings, showing a significant drop in performance on the Eyes ToM task when performed in dual-task combination with inhibition [$t(53) = 2.34$, $p = 0.02$]. There was no drop in performance on the Eyes Control task in the dual-task condition [$t(53) = 0.60$, $p = 0.60$]. Specific interference between inhibition and Eyes ToM is not due to suppression of spontaneously produced verbal labels.

This evidence suggests that ToM skills, as assessed by the Eyes task, are not automatic. Inhibitory skills may be important in ToM, perhaps at the level of response selection processing (Leslie & Thaiss, 1992; Leslie et al., 2004, 2005), although this has previously been tested in relation to false belief understanding only. The Eyes task assesses the relatively simple ability to interpret emotions from visual information, with no requirement to process multiple perspectives, predict behaviour, or follow a chain of events. However, the very task of selecting the most appropriate response from other plausible alternatives may invoke a selection processor. If this were the case inhibitory interference would also be expected in the Eyes Control task because this has the same requirement for response selection – however this result was not found in the current study. An alternative explanation for the role of inhibition in the Eyes ToM task may be the requirement to override person attributes which are automatically activated following presentation of facial features. Social

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attributes associated with gender and age are rapidly and spontaneously activated when viewing faces (e.g., Santos & Young, 2005). When asked to make a mental-state judgement about facial features as in the Eyes ToM task, participants may have to inhibit this spontaneously activated social information to accurately determine thoughts and emotions.

The use of the dual-task method has allowed us to directly address processing commonalities between EF and ToM tasks in healthy adults, which has implications for the contrasting patterns of results from studies of participants with impaired social understanding. Researchers have been quick to examine ToM in elderly and brain damaged populations and in neuroimaging studies with healthy participants. However, these studies have proceeded without critical information about the cognitive processes responsible for ToM in normal adults. Current results indicate that executive processes are recruited in both simpler ToM tasks of understanding emotions from visual stimuli and for complex social understanding where multiple perspectives have to be considered, self knowledge inhibited, and beliefs considered in relation to subsequent emotions or actions, as in the current Stories Tasks and other complex ToM paradigms such as understanding of false belief. These findings are in line with recent evidence from dual-task studies conducted by McKinnon and Moscovitch (2007), and support the notion of processing overlaps between EF and ToM found in neuropsychological studies (e.g., Stone et al., 1998), and in studies with children (e.g., Carlson et al., 2002) and elderly populations (e.g., German & Hehman, 2006). The current evidence that Stories tasks make high demands on EFs, irrespective of their mental-state content, should be borne in mind when making decisions about appropriate methods of assessing ToM in clinical populations, and interpreting deficits in performance in such tasks in the context of more general cognitive dysfunction.

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