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The role of working memory in rapid instructed task learning and intention-based reflexivity: An individual differences examination ☆

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ABSTRACT

The ability to efficiently follow novel task instructions (Rapid Instructed Task Learning, RITL) appears late in evolution, is required for successful collaborative teamwork, and appears to involve maintaining instructions in working-memory (WM). RITL is indexed by the efficiency in which the instructions are performed (RITL success) and by whether the instructions operate automatically (intention-based reflexivity). Based on prior normative work employing WM-load manipulations, we predicted that individual differences in WM would positively correlate with these RITL indices. Participants ($N=175$) performed the NEXT paradigm, which is used to assess RITL, and tests of choice reaction time, intelligence, and WM. Confirmatory factor analyses showed that, contrary to our predictions, successful performance in WM tasks did *not* predict RITL performance. Tests tapping general-fluid intelligence and reaction time positively correlated with RITL success. However, contrary to our predictions, RITL success positively correlated with *little* intention-based reflexivity. We suggest that for a RITL paradigm to produce intention-based reflexivity, its WM demand must be low, and, thus, performance does *not* reflect individual differences in WM.

1. Introduction

The ability to immediately and efficiently follow instructions has been labeled Rapid Instructed Task Learning (RITL) (Cole et al., 2013). According to these authors, "RITL is the process of rapidly (typically, on the first trial) learning a novel rule or task from instructions" (p. 2). While RITL enabled our ancestors to hunt in teams, it enables modern humans to succeed in teamwork during medical surgery, sports, etc. What characterizes these instances is that team members instruct one another on the fly and are expected to follow instructions immediately and proficiently, not having the luxury of practicing the instructions before carrying them out.

RITL might also be among the most recent evolutionary innovations that made us who we are. Arguably, Homo sapiens have gained an evolutionary advantage from their ability to establish complex forms of collaboration (e.g., Herrmann et al., 2007; Tomasello et al., 2012).

Recent research efforts (reviewed below) have advanced our knowledge on the normative aspects of RITL. Yet, very little is known regarding individual differences in this ability. Accordingly, *our goals were to study individual differences in the ability to immediately and efficiently follow simple instructions, and to examine how these differences correlate with relevant individual differences constructs, especially working memory (WM).* Below, we provide a brief review of the relevant literature.

1.1. Rapid Instructed Task Learning (RITL)

In typical RITL tasks, the instructions are simple and consist of novel combinations of familiar elements (Cole et al., 2011). Although RITL reflects learning, it differs markedly from skill acquisition, a widely studied form of learning. First, a critical feature of RITL is that the instructions must be immediately and proficiently followed, without having the benefit of prior practice. In contrast, in typical skill acquisition studies, the focus is on how (usually extensive) practice leads to improved performance. Furthermore, whereas RITL studies often involve simple tasks, typical tasks in skill acquisition studies are complex (e.g., mirror drawing, reading). Finally, studies on skill acquisition usually involve a single task that remains relevant for at least the entire duration of the experiment. In contrast, since the focus in RITL is on the first

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trial or the first few trials following the instructions, studying it characteristically involves many different novel tasks, each relevant for a very short duration and typically executed only a few times (Cohen-Kdoshay and Meiran, 2007; Cole et al., 2013).

Recent computational modeling studies suggest that RITL is implemented for behavioral performance by rapid formation of new synaptic connections (Bugmann, 2012) or in dual-route architectures in which one route is slow, but flexible, and the other route is fast, yet rigid (Huang et al., 2013; Ramamoorthy and Verguts, 2012). Neuroimaging studies highlight the importance of anterior regions of the prefrontal cortex with the brain activation dynamics shifting to more posterior and sub-cortical brain regions over the course of a few trials of training (for a review, see Cole et al., 2013).

1.2. Behavioral markers of RITL efficiency

Skill is reflected in fluency but also in automaticity, the difficulty avoiding skill application. For example, the difficulty suppressing the urge to read words leads to the Stroop effect, where participants are asked to ignore the words and name the ink color in which they are written. Moreover, the Stroop effect increases with reading proficiency, at least at the early stages of learning to read (Schiller, 1966), a fact that suggests an increase in the urge to read the words.

Like skill, RITL is also reflected in performance fluency (Cohen-Kdoshay and Meiran, 2007; Meiran et al., 2015; Ruge and Wolfensteller, 2009), behavioral automaticity (Cohen-Kdoshay and Meiran, 2007; De Houwer et al., 2005; Liefooghe et al., 2012; Meiran et al., 2015; Wenke et al., 2007), and also in brain-recorded automatic motor plan activation (Everaert et al., 2014; Meiran et al., 2014). We chose to describe RITL-related automaticity as "*intention-based reflexivity*" (Meiran et al., 2012), mainly in order to denote fact that in RITL, only one characteristic of automaticity is seen. This characteristic indicates that the newly instructed plan "gained a life of its own" and became autonomous. In other words, this plan is (perhaps, partly) executed even when another task is required (Bargh, 1992; Tzelgov, 1997).

1.2.1. Intention-based reflexivity and inhibition

Standard conflict effects, such as the Stroop or the flanker effect (Eriksen, 1995) are taken to reflect both automaticity and its control: behavioral inhibition (Friedman and Miyake, 2004). Both viewpoints are valid (see Meiran (2010)) because behavior is the outcome of two opposing forces: (a) those creating the urge to execute a given response/process (e.g., the habit of reading words, in case the of the Stroop task; MacLeod, 1991); and, (b) the forces that permit one to overcome this inappropriate urge and execute the required task, instead. Although when we describe the latter, we refer to "behavioral inhibition", we do not commit ourselves to some inhibitory mechanism (see below). Instead, we refer to "inhibition" more generically, as all the processes permitting one to overcome inappropriate urges. Intention-based reflexivity is similar to automaticity-related effect in this respect, except that the urge to execute the task results from WM representations (Meiran et al., 2012; Oberauer et al., 2013) rather than habits that are stored in long-term memory (Squire, 2004).

1.3. WM in RITL and intention-based reflexivity – Normative studies

To achieve highly efficient performance without prior practice, instructions in RITL tasks are typically simple (Kaplan and White, 1980), must be immediately stored, and must be highly accessible. Importantly, WM has been described as "a system devoted to providing access to representations for goal-directed processing" (Oberauer, 2009, p. 47), with an emphasis on novel bindings between familiar elements, which is done in a limited-capacity sub-system of WM (especially Oberauer et al., 2013). These considerations, together with the implications of the prefrontal cortex (Cole et al., 2013) known to be related to WM, suggest that RITL relies on WM (see Engle et al. (1991); Gathercole, et al. (2008); Yang et al. (2014)).

This hypothesized link between RITL and WM has been addressed in normative studies employing a WM load manipulation. These studies show that RITL performance drops (Yang et al., 2014) and intention-based reflexivity is eliminated (Cohen-Kdoshay and Meiran, 2007; Meiran and Cohen-Kdoshay, 2012) under WM-load. In a series of studies (as yet unpublished; Pereg and Meiran, submitted), we showed similar effects of WM load in the NEXT paradigm that we used here.

To summarize, despite the fact that intention-based reflexivity is theoretically linked to two opposing forces (i.e., the urge to execute the instructions and the inhibition of this urge), the normative studies seem to suggest that WM plays an important role in the effect. We thus asked whether this also holds true for individual differences.

1.4. Individual differences in following directions

Although individual differences in modern RITL tasks have barely been studied, following-directions tasks that resemble RITL in some respect have been examined since the beginning of the 20th century. Many of these studies related following directions to intelligence, and we review them partly because of the close link between intelligence and WM (Kane et al., 2005).

"Following Directions" was one of the tests that was included in the Army Alpha intelligence examination (see Ottis (1918)). A somewhat similar test with the same name is one of the two tests indexing the "Integrative Processes" factor in the ETS - Kit of factor-referenced cognitive tests (Ekstrom et al., 1976), which is comprised of tests shown to tap individual differences factors (see also Hattrup et al. (1992)). In the present study, we employed a following-directions test called "Comprehension". Among the eleven intelligence tests studied by Meiran and Fischman (1989), Comprehension showed the highest correlation with the general intelligence factor ($r=.77$) in that study. Engle et al. (1991) found positive correlations between following directions and WM, ranging from .30 to .47. Yet, in this study, the developmental trajectories were different for WM measures and "Following Directions", suggesting that these two constructs are not identical.

Finally, despite their similarity, classic following-directions tests differ from RITL in the requirement to comprehend complex task descriptions, and their focus on response correctness. In contrast, RITL tasks emphasize the ability to efficiently execute simple instructions, and the primary measure is reaction-time (RT). These differences seem crucial since what arguably matters mostly for general intelligence is the ability to "structure" the task in its initial stages (Ackerman, 1988; Bhandari and Duncan, 2014).

1.5. The current study

The goal of the present work was to examine the role of WM in RITL efficiency (as assessed in what we called "a modern RITL task") and intention-based reflexivity by focusing on the individual differences correlations between these constructs, as assessed using Structural Equations Modeling (see more below).

We were able to identify only one study on individual differences in RITL (Stocco and Prat, 2014) that showed that bilinguals, known to have especially efficient executive functions (Bialystok et al., 2012), outperformed monolinguals. Additionally, only among bilinguals, there was an increase in the level of oxygenated blood supply to the basal ganglia when novel rules were executed,

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