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Short communication

Learning, working memory, and intelligence revisited

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Abstract

Based on early findings showing low correlations between intelligence test scores and learning on laboratory tasks, psychologists typically have dismissed the role of learning in intelligence and emphasized the role of working memory instead. In 2006, however, B.A. Williams developed a verbal learning task inspired by three-term reinforcement contingencies and reported unexpectedly high correlations between this task and Raven's Advanced Progressive Matrices (RAPM) scores [Williams, B.A., Pearlberg, S.L., 2006. Learning of three-term contingencies correlates with Raven scores, but not with measures of cognitive processing. Intelligence 34, 177–191]. The present study replicated this finding: Performance on the three-term learning task explained almost 25% of the variance in RAPM scores. Adding complex verbal working memory span, measured using the operation span task, did not improve prediction. Notably, this was not due to a lack of correlation between complex working memory span and RAPM scores. Rather, it occurred because most of the variance captured by the complex working memory span was already accounted for by the three-term learning task. Taken together with the findings of Williams and Pearlberg, the present results make a strong case for the role of learning in performance on intelligence tests.

Keywords: Intelligence; Learning; Three-term contingency

1. Introduction

Although psychologists generally agree on the importance of assessing intelligence, there has never been a consensus as to the exact nature of this construct (Intelligence and its Measurement: A Symposium, 1921; Neisser, 1981; Neisser et al., 1996; Sternberg and Detterman, 1986). There is even a lack of agreement on whether intelligence is comprised of one factor (‘*g*’; Jensen, 1968; Spearman, 1927), two factors, (e.g., fluid vs. crystallized; Horn and Cattell, 1966), or many factors (e.g., either multiple factors or a hierarchy of factors; Carroll, 1993; Sternberg, 1985).

Recently, there has been growing interest in the relation between working memory and intelligence. Indeed, some researchers (e.g., Engle et al., 1999; Engle, 2002; Kyllonen and Christal, 1990) have claimed that working memory capacity *is* intelligence. In contrast, Ackerman et al. (2002, 2005) argued, based on both a single study including an unusually large number of ability measures and a meta-analysis of 86 samples, that working memory and intelligence are not isomorphic, and that working memory is just one of a number of highly correlated abilities.

In the midst of the controversy concerning the role of working memory and intelligence, a new study by Williams and Pearlberg (2006) suggests that learning, in particular learning three-term contingencies, may be even more predictive than working memory in predicting intelligence (Snow et al., 1984). The Williams and Pearlberg findings stand in contrast to early findings showing low correlations between learning on laboratory tasks and intelligence test scores (Woodrow, 1938, 1946), which caused many researchers to dismiss the role of learning in intelligence.

In their first experiment, Williams and Pearlberg (2006) found that their three-term learning task correlated with the Raven's Advanced Progressive Matrices (RAPM) (Raven et al., 1998), but two other learning tasks (i.e., free recall and paired associates) did not. In a second experiment, they observed that the three-term learning task did not correlate with working memory and processing speed, despite the fact that these measures also correlated with the RAPM, which is the “gold standard” measure of fluid intelligence. Taken together, these findings strongly suggest that learning may be an important contributor of unique variance in intelligence test scores, contrary to previous reports

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that individual differences in working memory capacity explain nearly all of the variance.

Most studies examining the correlations among several cognitive tests report positive correlations between all cognitive measures (for a review, see Ackerman et al., 2005), which are presumed to indicate the existence of a general ability ("*g*") common to all measures (Spearman, 1927). Williams and Pearlberg's failure to find significant correlations between their learning task and speed and working memory is contrary to such findings. To further test whether learning and working memory make independent contributions to predicting performance on intelligence tests, the present study examined the relation between three-term contingency learning (using both a verbal and nonverbal version of this task), working memory (using both verbal and nonverbal), and fluid intelligence (using the RAPM).

2. Method

2.1. Participants

Sixty Washington University undergraduates (30 male and 30 female) participated. Participants completed a health questionnaire form to screen for visual problems, neurological disease, and depression. In addition, a near vision acuity test was administered using a Wormington Card (Guilden Ophthalmics, Elkin Parks, PA) to ensure that participants would be able to accurately perceive the stimuli on the computer screen.

2.2. Apparatus

Stimuli for the computerized tasks were presented on a 30 cm × 23 cm flat screen monitor equipped with Touchware Software S64 SR4 (3M Touch, St. Paul, MN). All computerized tasks were programmed in E-prime 1.1 (Psychology Software Tools, Pittsburgh, PA). Responses were made either using a computer mouse, the computer keyboard, or vocally (and recorded using an Olympus VN-900PC digital recorder).

2.3. Procedure

Each participant completed a 2-h session individually. Following the health questionnaire and vision test, participants performed the following sequence of tasks: the WAIS – III vocabulary test (Psychological Corporation, 1997), the verbal three-term learning task, a verbal working memory task, the RAPM, a nonverbal three-term learning task, and two nonverbal working memory tasks. Participants were given a brief break every 30 min throughout the session.

2.3.1. Verbal three-term contingency learning task

In this verbal learning task (Williams and Pearlberg, 2006), participants were told to learn the associations between each of the ten cue words (e.g., lie) and the list of three associated memory items (e.g., fan, rim, dry). There were four blocks of learning trials, each of which was followed by a test block. Both the learning and test blocks were self-paced.

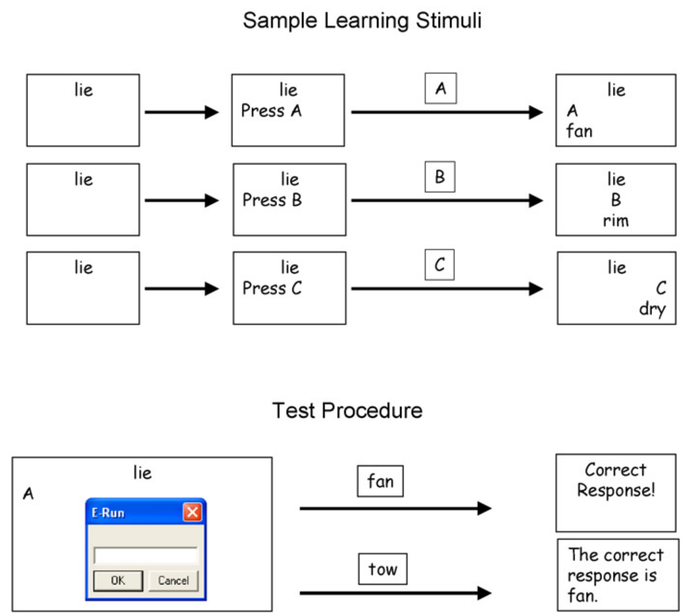

Fig. 1. Examples of learning and test trials from the verbal three-term learning task.

On learning trials, participants were first shown a cue word (e.g., lie) followed by the prompt, "press A", as shown in Fig. 1. Once the participant pressed the cued letter, the prompt disappeared and the cued letter "A" and the associated memory item (e.g., fan) appeared in the bottom right hand of the screen. The cue word, letter, and the memory item remained on the screen until the participant pressed the enter key. Then, the cue word (i.e., lie) was shown again followed by the second prompt (i.e., "press B") and after pressing the cued letter, the letter "B" and the second memory item (e.g., rim) remained on the screen until the participant pressed enter. The third prompt (i.e., "press C") then appeared beneath the cue word. Again, the prompt disappeared once the participant pressed the cued letter, and the letter "C" and the third memory item (e.g., dry) appeared in the bottom left of the screen. For each learning block, this cycle was repeated until all of the 10 cue words with their 3 associated memory items had been presented. The order of presentation for the 10 cue words and their associated memory items was different in each of the 4 learning blocks.

On test trials, the participant viewed a cue word and the first prompt (i.e., "A"), as well as a textbox located in the bottom center of the screen (see Fig. 1). The participant was asked to recall the word associated with the cue word and prompt by typing the correct word into the textbox. For example, if the participant saw the cue word *lie* and the letter *A*, then the correct response was to type the word *fan* into the textbox. Alternatively, the participant could type the letter "x" into the textbox if the associated memory item could not be recalled. Participants were given feedback after each response (see Fig. 1). Next, the participant was shown the same cue word followed by the second prompt (i.e., "B") and a textbox and then the third prompt (i.e., "C) and a textbox. The 10 cue words and the 3 prompts constituting the test block were presented in the same order as in the preceding learning block. Following Williams and Pearlberg (2006), performance