Development and Validation of a Shortened Language-Specific Version of the UNRAVEL Placekeeping Ability Performance Measuring Tool

Agata Kopacz, Cezary Biele, and Aldona Zdrodowska

Laboratory of Interactive Technologies, National Processing Institute

ABSTRACT

The current study aimed to develop a shortened language-specific (Polish) version of the UNRAVEL task (Altmann, Trafton, & Hambrick, 2014) and to verify whether the adaptation yields valid and reliable data about placekeeping ability. Since the original procedure is intended to investigate task performance referring to placekeeping operations under conditions of task interruptions, we used this tool in the context of a multitasking situation. The adopted version differs from the original in that we reduced the number of steps in the procedure and changed the rules set, using an acronym WINDA (a word meaning *elevator* in Polish). Participants were asked to try to keep their place in the WINDA sequence, make a two-alternative forced choice regarding one feature of a presented stimulus, and to continue the task after the interruption at the place where they had left off. Similarly to the original task, reliability of sequence errors was high, suggesting that the WINDA task is suitable for measuring individual differences in placekeeping performance. The results suggest that the adaptation process that we employed to create the WINDA task can be utilized to generate other language adaptations of this tool (characterized by different levels of difficulty) targeted at specific subject groups.

KEYWORDS

placekeeping ability
interruptions
multitasking
WINDA procedure
language-specific adaptation of the UNRAVEL task

INTRODUCTION

The authors of the UNRAVEL procedure (Altmann, Trafton, & Hambrick, 2017) investigated the effect of interruptions on task performance. Interruptions are breaks in the current activity, often unexpected, that can introduce a new task, thus forcing a person to move from one task to another in an unplanned manner (Miyata & Norman, 1986). This generates a multitasking situation in which more than one task is performed in the same time period. In the current project, we used the placekeeping ability measuring tool in the context of a multitasking situation with interruptions, similar to multitasking situations present in most everyday activities. The ability to sequence and execute tasks in a specific order without omitting or repeating steps, seems to be responsible for the coordination of multiple processes.

Altmann, Trafton, and Hambrick (2014) created a procedure that engages executive processes, in which the task is to focus attention on the correct element and to navigate to the next task-relevant element. They used a sequential task where steps have to be performed in a particular sequence, and correct performance depends on placekeeping in the sequence. This procedure enables the generation of complex and interpretable data on errors in the selection of sequential actions. The main finding of the original UNRAVEL study was that even momen-

Corresponding author: Agata Kopacz, Interactive Technologies Laboratory, National Information Processing Institute, al. Niepodległości 188b, 00-608, Warsaw. E-mail: agata.kopacz@opi.org.pl

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tary interruptions may lead to an increased chance of resuming at the wrong step in a sequential task during a cognitively engaging activity. The researchers examined the potential of their procedure to produce individual differences and verified the reliability of sequence errors as a measure of individual differences in placekeeping operations. The reliability of sequence errors was high, suggesting that the UNRAVEL task is a reliable tool, suitable for measuring individual differences in sequential performance.

Scientists postulate cognitive correlates of placekeeping ability; for example, fluid intelligence, in the sense of the ability to solve novel problems, or working memory, which is the capacity to hold and manipulate information in the mind for a period of time (Burgoyne, Hambrick, & Altmann, in press). In another study, Hambrick, Altmann, and Burgoyne (2018) demonstrated that placekeeping ability correlates significantly with fluid intelligence, working memory, and perceptual speed. At the same time, the results indicated that placekeeping ability is distinct from working memory capacity and more related to long-term memory of linear sequences (Burgoyne et al., in press).

The current project aims to develop a shortened, language-specific (Polish) version of the UNRAVEL task and to verify whether the adaptation yields valid and reliable data about placekeeping performance. The goal of the adaptation was twofold. Firstly, to recreate a valid and reliable tool for use in specific language settings – in this case Polish. Secondly, to shorten the procedure for participants with limited cognitive abilities, such as older people.

METHOD

Participants

The study was conducted among 121 younger adults (61 undergraduates from the SWPS University of Social Sciences and Humanities, aged between 19 and 44, M = 23.62, SD = 4.99) and older adults (60 students from the University of the Third Age in Warsaw, aged between 64 and 75, M = 68.3, SD = 3.14). The inclusion criterion for older adults included obtaining at least 27 points ("lack of dementia") in the Mini Mental State Examination (Folstein, Folstein, & McHugh, 1975).

The Experimental Task

The WINDA task is a Polish adaptation based on the original version of the UNRAVEL task (Altmann et al., 2014). In order to make it easier for participants to remember the task rules of the Polish version, in the same way as in the original version of UNRAVEL, both the sequence of the rules (steps) and their content were arranged into the keyword WINDA (meaning elevator in Polish). Each letter of the acronym WINDA identifies a step and the letter sequence defines the order in which the steps have to be performed. Each step of the WINDA sequence requires a two-alternative forced choice relating to one feature of a presented stimulus. For each step, the letter in the sequence mnemonically relates to one of the two candidate responses: *W* or *M*, *I* or *R*, *N* or *P*, *D* or *G*, *A* or *Z* (e.g., *W* for *Wielka* [uppercase], *N* for *nieparzysta* [odd]; their opposites are *M* for *mała* [lowercase], and *P* for *parzysta* [even], respectively). Each stimulus consists of two characters – a letter and a digit – randomly selected from the following set: *B*, *E*, *T*, *Y*, *1*, *2*, *8*, or *9*. Each stimulus has various features, such as font size or location on screen. Figure 1, Panel A illustrates two sample stimuli.

In the original version, the seven rules relate to various features of the stimuli. Three of them involve some visual attributes: the font style of one character (underline or italic), the color of one character (red or yellow), and one character's position outside a grey outline box (above or below). Not all the steps are directly perceptual. Two of them refer to digits: one step involves deciding whether the digit is even or odd and the second involves deciding whether the number is below or above 5. Another two refer to letters: one step requires deciding whether the letter in the stimulus is near to or far from the start of the alphabet and the second is deciding whether the letter is a vowel or a consonant. In the Polish adaptation, analogous rules are made, but the number of rules in the procedure is reduced from seven to five because of the older age of half of the participants and the high level of difficulty of the task: two rules refer to digits, two refer to letters, and one rule is perceptual. Table 1 shows the choice rules and the responses for all five steps.

The rules of the task and candidate responses are also unique to each step, meaning that a participant's response shows which step he or she thought was correct during that trial, and whether there was a *sequence error*. If the selected step was correct, but the response was incorrect for a given stimulus, a *nonsequence error* occurred.

The stimulus changes after each step. The sequence is performed in a cycle, with *A* followed immediately by *W*. This continuous performance can be interrupted many times. Interruptions occurred every four steps on average (less than the length of the WINDA sequence), so that interruptions would not always occur at the same point in the sequence. During interruptions, the participant's task was to type four letters (a code) into a box and press the Return key to get back to the primary task. The code letters were randomly sampled from the alphabet, excluding the main acronym letters so as to avoid potential interference between the code and the main acronym letter signifying the place in the sequence. If the participant typed the letters correctly, pressing the Return key ended the interruption and the next stimulus

TABLE 1.
Rules of the WINDA Task

Step	Candidate responses	Choice rules	Rule target type	Meaning of rules
W	w m	litera jest Wielką czy Małą literą	letter	the letter is uppercase or lowercase
I	i r	cyfra jest Inna czy Równa 1 lub 8	digit	the digit is other than 1 or 8 or is 1 or 8
N	n p	cyfra jest Nieparzysta czy Parzysta	digit	the digit is odd or even
D	d g	znak jest na Dole czy na Górze ramki	visual	the character is below or above the box
A	a z	litera jest w alfabecie bliżej litery 'A' czy 'Z'	letter	the letter is nearer to A or to Z in the alphabet

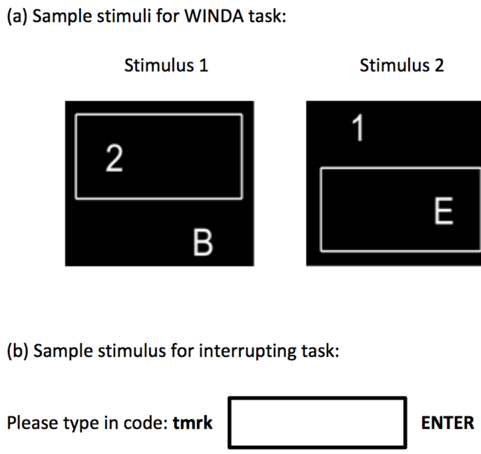

FIGURE 1.

Panel A: Two sample stimuli for the WNIDA task. Panel B: Sample stimulus for the interrupting task.

in the primary task was displayed. If the participant made any error typing the code, pressing Return cleared the box and displayed a new set of letters to type. Figure 1, Panel B shows a sample interruption stimulus.

SEARCHING FOR KEYWORD (ACRONYM)

In order to find a keyword containing specific letters – one from each pair of candidate responses, it was necessary to search the dictionary of Polish words. Accordingly, to generate a list of words fulfilling the above conditions, a computer program was created in Python, which used a morphosyntactic dictionary from a morphological project (Weiss & Miłkowski, 2013). After the dictionary search, the program selected a list of 43 words, including only two nouns in the nominative: PIGWA (*quince* in Polish) and WINDA (*elevator* in Polish). For the study, we decided to choose the word WINDA due to its connotations; it is associated with moving in a specific order, thus referring to the sequence of rules in the experimental task.

Procedure

Participants were tested individually. A session began with detailed instructions on the WINDA task, showing how the operations for each step were mnemonically linked to the letter for that step. A summary screen presented the decision rules for each step and the letters spelling out the acronym. Participants had unlimited time to learn the task rules and steps. To ensure that participants understood the task and remembered the steps, there were 16 training trials during which the participants were required to provide a correct response to each stimulus. This training session included an interruption to the primary stimulus on two occasions, in order to illustrate to participants how they were supposed to deal with interruptions. Participants were asked to try to keep their place in the WINDA sequence and, after an interruption, to continue the task from where they had left off. The experiment proceeded after the participants had successfully completed the training session. The experimental session consisted of four blocks, each with 12 trials and 2 interruptions, making 48 trials and 8 interruptions in total. A session took about 20 minutes to complete. No feedback was given to participants during the experiment.

ANALYSES

To test the properties of the WINDA task and to compare it to the original UNRAVEL task, we re-enacted a set of analyses completed by Altmann et al. (2014). The original paper included two experiments differing in the difficulty of the interruption task used. In Experiment 1, the interruption task was more difficult because the interruption code was four characters long and comprised letters and digits. In Experiment 2, the task was easier, as the code included only letters and was two characters long. The difficulty of the interruption task in WINDA mirrors the one from the original Experiment 1 (with a 4-character interruption string constructed using only letters). Consequently, in the following analyses, we compared the results of WINDA with the results of the first of the UNRAVEL experiments.

The following section contains a description of the four main analyses. Analysis 1 concentrated on the effects of the interruption, and its goal was to compare performance across trials following the interruption. Analysis 2 examined the differences between steps in the WINDA sequence, mainly in order to check whether the difficulty of the step interacted with the interruption effect. Analysis 3 focused on sequence errors as a function of the distance from the correct step (the number of steps skipped or repeated within the sequence). Analysis 4 examined the reliability of sequence errors as a possible measure of individual differences.

Before the analyses, we also checked whether there were any subjects who consistently underperformed in Trial positions 2, 3, and 4 (excluding Position 1, i.e. directly after the interruption). We decided that subjects whose score was at least 2 *SD*s below the mean on either sequence error or nonsequence error would be excluded from all the analyses because their low score likely stemmed from the fact that they did not understand the task rules. Analysis revealed five such subjects. They were excluded from the data.

Analysis 1. Interruption Effects

In this analysis, we examined the following measures: sequence errors, nonsequence errors, and response time. Sequence errors were defined as the proportion of trials where the answer given did not follow the WINDA sequence. Nonsequence errors were defined as the proportion of trials in which the answer was one of the answers expected according to the WINDA sequence but was incorrect for the stimulus presented. In addition to the analysis of errors, we also performed analyses of response latencies for the correct answers. Prior to the analyses, reaction times were standardized within age groups because of the potential substantial differences in reaction times between the younger and older adults in our experiment (Dykiert, Der, Starr, & Deary, 2012; Woods, Wyma, Yund, Herron, & Reed, 2015). After the standardization, answers from trials with reaction times deviating more than 2 *SDs* from the mean were excluded from the analyses.

For this analysis, the data was separated by trial position (1 through 4) after interruption, where Position 1 was the first one directly after the interruption. In order to determine the run length, we used similar criteria as those used by Altmann et al. (2014). For both groups, more than half of the runs were at least four trials long, and fewer than half were five trials long, so although the periods without the interruption could be longer than four, we analyzed the data only for the first four trials because of the increased variability caused by a small number of observations. For this analysis, the factor of step (W, I, N, D, A) was omitted and the impact of the step was analyzed and reported in Analysis 2.

RESULTS

The sequence error, nonsequence error, and response latency data are plotted in Figure 2, Panel A. For each measure, we conducted one-way analyses of variance (ANOVA) of Position (1, 2, 3, and 4) and follow up post-hoc pairwise comparisons if needed.

For sequence errors, there was significant main effect of position, $F(2.32, 266.54) = 32.20$, $p < .001$, $\eta_p^2 = .22$. The post-hoc pairwise comparisons with the Bonferroni adjustment, performed to further examine the effect of position, indicated that the results revealed a pattern similar to the one obtained by Altmann et al. (2014), with significantly higher error rates for Position 1 compared to any other position (2 to

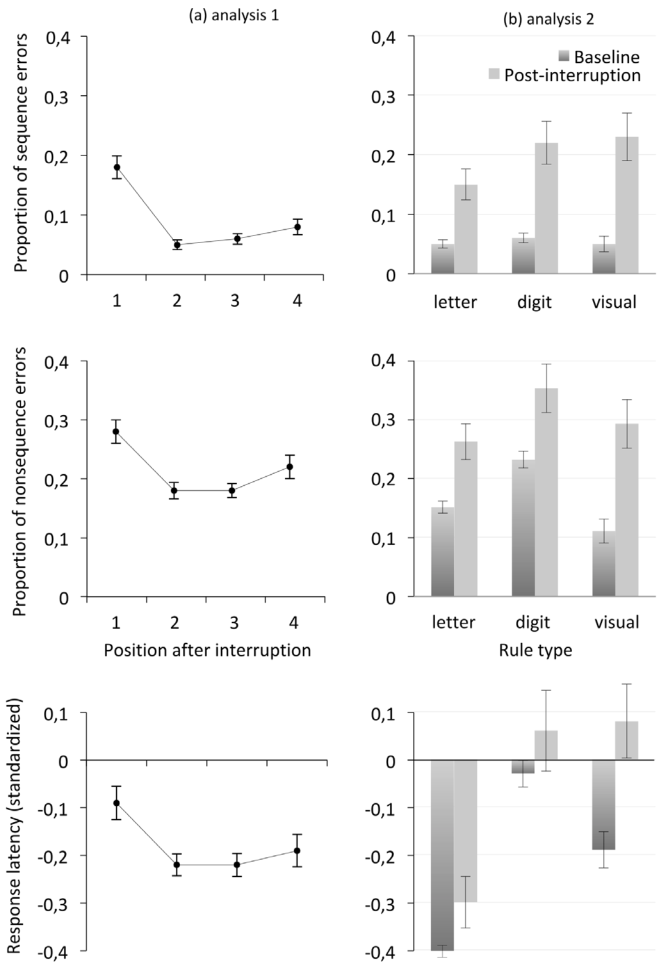

FIGURE 2.

Panel A: Performance as a function of a position after interruption with sequence errors in the top panels, nonsequence errors in the middle panels, and response latencies in the bottom panels. Panel B: Performance as a function of rule type within the WINDA procedure.

4, $p < .001$ in all cases). The error rates for Positions 2, 3, and 4 did not differ significantly from one another.

For nonsequence errors, there was again a significant main effect of position, $F(2.72, 312.21) = 9.90$, $p < .001$, $\eta_p^2 = .08$. To follow up on effect of position, we performed post-hoc pairwise comparisons with the Bonferroni adjustment. The error rate was significantly higher for Position 1 than for Positions 2 and 3 ($p < .001$ in all cases) and marginally higher for Position 4 ($p = .085$). None of the latter differed significantly from one another.

For reaction times, there was a significant main effect of position, $F(2.60, 296.18) = 4.15$, $p < .01$, $\eta_p^2 = .04$. The post-hoc pairwise comparisons with the Bonferroni adjustment, performed to further examine the effect of position on reaction time, indicated significantly higher response latency on Position 1 compared to Position 2 ($p < .01$ in both cases) and 3 ($p < .05$). The response latencies for Positions 2, 3, and 4 did not differ significantly one from another.

DISCUSSION

Our analyses for the WINDA task paralleled Altmann et al.'s (2014) results for UNRAVEL for the sequence error rates. The mean sequence error on Position 1 was significantly higher than the error rates on Positions 2–4. For nonsequence errors, our results resemble the pattern obtained for sequence errors, with significantly higher error rates on Position 1 than on any other position. According to the explanation proposed by Altmann et al. (2014), this means that interruptions can affect global attentional processing and disrupt both placekeeping and step-specific operations.

Similarly to Altmann et al. (2014), the results for response latency were significantly higher for Position 1 than for Positions 2 and 3, although the difference between Positions 1 and 4 that Altmann et al. (2014) observed was not seen here. Consequently, the size of the main effect of position for response latency ($\eta_p^2 = .04$) was smaller than the effect size for sequence errors ($\eta_p^2 = .22$). This too is in line with Altmann et al.'s (2014) results. Altmann and Gray (2008) postulate in their model that response latencies depend on the accessibility of the most active item, whether or not this is the target, and are less sensitive to a decrease in activation of the target. Retrieval accuracy, in contrast, depends on the activation difference between the target and the most active item, and in a situation of high distractor accessibility, the probability of a retrieval failure will be high.

Analysis 2. Rule Type Effects

In this analysis, we examined the effect of rule type (see Table 1) on the three measures examined in Analysis 1. The main goal of this analysis was to verify whether different rule types (letter, digit, or visual), which may display differences in subjective difficulty, would interact differently with the interruption effects. In other words, whether different rule types might be easier to remember when being performed during a sequence (as they may leave traces in episodic memory), thus modulating the frequency of sequence errors. Altmann et al. (2014) investigated similar problems using step analysis for each of the original rules (*U*, *N*, *R*, *A*, *V*, *E*, *L*). We decided to use a different approach and analyze rule types, as the step analysis may be prone to the serial-position effect (primacy and recency), producing artifact interaction effects that impede the interpretation of the results.

We evaluated rule type effects separately from the position effects in Analysis 1 because of an excessively high count of missing cases with these two factors included simultaneously in the design. To address this problem, we used a solution modeled after Altmann et al. (2014). We created a new factor named context, with the following levels: post-interruption (Position 1 from Analysis 1) and baseline (Positions 2, 3, 4, and 5). Combined aggregation by rule type and position resulted in 31 missing cases for sequence and nonsequence errors. For the response latency the number of missing cases was higher (64 missing) because only the correct answers were included in the analyses.

RESULTS

The data is plotted in Figure 2, Panel B, as for Analysis 1, with different bar shades indicating rule types. For each measure, we performed a Rule type (letter, digit, visual) × Context (post-interruption, baseline) ANOVA and follow-up post-hoc pairwise comparisons if needed. For sequence errors, there was a significant effect of context $F(1, 84) = 43.25$, $p < .001$, $\eta_p^2 = .34$. No other main effects, including rule type or interaction, were significant. The results indicate that the rule type did not influence interruption effects.

For nonsequence errors, there were significant main effects of rule type, $F(1.82, 152.83) = 7.07$, $p < .01$, $\eta_p^2 = .08$, and context, $F(1, 84) = 38.61$, $p < .001$, $\eta_p^2 = .32$. In order to examine the rule type differences, we conducted a post-hoc analysis with Bonferroni correction. The results indicated that the digit rule type was significantly more difficult than either the letter rule or the visual rule ($p < .01$ in all cases), which did not differ significantly from one another.

For response latency, both main effect of rule type, $F(2, 102) = 22.96$, $p < .001$, $\eta_p^2 = .31$, and context, $F(1, 51) = 9.11$, $p < .01$, $\eta_p^2 = .15$, were significant. In order to examine the rule type and context differences, we conducted a post-hoc analysis with Bonferroni correction. The results indicated that the response latency was significantly shorter for the letter rule than for both other types of rules (all $p < .001$ in all cases). The digit rule and visual rules did not differ from one another. The second post-hoc analysis revealed that response latencies were longer post-interruption.

DISCUSSION

Altmann et al. (2014) hypothesized that different rules could have different influences on the sequence errors because of their difficulty and, in effect, the utilization of working memory. Our tests of the influence of rule type show that this did not happen in the WINDA procedure, as the interruption effect was constant for each of the tested rule types. This means that particular rules (letter, digit, visual) did not have any specific influence on sequential control, despite having different levels of difficulty as indicated by the results of the nonsequence error analysis (digit rules being more difficult than letter and visual rules). This rule type effect seems to reflect a greater difficulty of one step compared to others, namely the *I* rule: the digit is other than 1 or 8 or equal to 1 or 8, which requires more information to be remembered without a visual clue. The differences in the difficulty of individual steps are best illustrated by the *I* and *W* rules. The average nonsequence error for this rule is significantly higher (M = 0.31, SE = 0.01) than the number of errors for the W rule, which requires only a visual judgment of whether the presented letter is uppercase or lowercase (M = 0.07, SE = 0.01). However, the number of sequence errors for both aggregated types of rules and individual steps is similar, indicating that the amount of effort put into performing a given step remains unconnected with their sequential processing.

Also, response latencies for rule types seem to track differences in the difficulty of particular rule type – the task is most difficult for the digit rules, which is demonstrated by their having the highest response latency (which was significantly higher for digit rules than for the letter rules, and numerically than for the visual one). Altmann et al. (2014) suggested that different steps of the UNRAVEL task could be replaced by others and still provide similar results. Our study, resulting in no interaction of rule type and interruption effects, makes the WINDA task a potentially good adaptation of the UNRAVEL procedure.

Analysis 3. Sequence Error Distributions

Next, we examined the distribution of sequence errors over distance (−2, −1, +1, +2), for post-interruption (Position 1, first error directly after the interruption) and baseline (Positions 2, 3, and 4) contexts. The analysis aims to test for further evidence for gradient and symmetry effects in perseverations and anticipations found in previous works (Altmann et al., 2014; Trafton, Altmann, & Ratwani, 2011). Perseverations are defined as negative sign errors (e.g., −2) and anticipations refer to positive sign errors (e.g., +2). The distance relates to the number of steps repeated or skipped within the sequence when a sequence error occurs. For example, a −1 error refers to the situation in which a *W* trial comes after a *W* trial, whereas a +1 error occurs when an *N* trial comes after a *W* trial.

RESULTS

The data for the sequence error distributions is plotted in Figure 3. The results of a two-way distance (−2, −1, +1, +2) × context (post-interruption, baseline) within-group ANOVA revealed significant main effects of distance, $F(2.47, 284.36) = 16.06$, $p < .001$, $\eta_p^2 = .12$, and context, $F(1, 115) = 58.80$, $p < .001$, $\eta_p^2 = .34$, as well as a significant interaction between distance and context, $F(2.66, 306.41) = 15.46$, $p < .001$, $\eta_p^2 = .12$.

To further examine the interaction between distance and context and test the distribution of sequence errors for the gradient effect, we conducted pairwise contrasts between neighboring distances (see Table 2) in a one-way ANOVA for both contexts. Since the contrasts were nonorthogonal (two per gradient) we set significance level at $\alpha = .025$ (Bonferroni correction). Analyses revealed two out of four possible[1] significant gradient effects – for perseveration in the post-interruption context and anticipation in the baseline context. For the two remaining contrasts, sequence errors at the smaller distance were numerically more frequent than those at the greater distance.

Finally, we tested for (a)symmetry in perseveration and anticipation errors, with −1 versus +1 contrasts as proxies. Analyses revealed that in the post-interruption context, perseverations were significantly more frequent, while in the baseline, the participants were significantly more prone to anticipation errors.

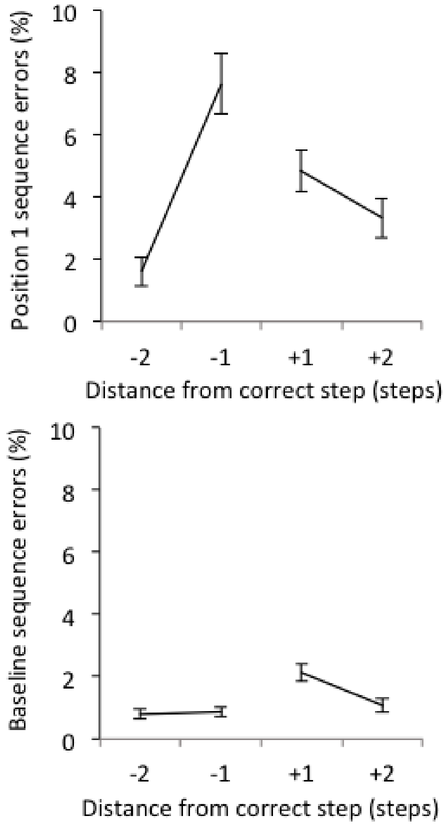

FIGURE 3.

Sequence errors as a function of distance from correct step (e.g., a *W* that follows a *W* would be a −1 error, and a *N* that follows a *W* would be a +1 error) with post-interruption context in the left panel and baseline context in the right panel.

TABLE 2.

Inferential Statistics for Pairwise Contrasts Between Neighboring Levels of Distance

	Baseline			**Post-interruption**		
Distances	$F(1, 115)$	p	η_p^2	$F(1, 115)$	p	η_p^2
−2,−1	0.19	0.661	0.00	39.37	**< .001**	0.26
−1,+1	19.97	**< .001**	0.15	6.97	**0.009**	0.06
+1,+2	8.43	**0.004**	0.07	3.58	0.061	0.03

Note. Boldface values are significant at Bonferroni-corrected $\alpha = .025$.

DISCUSSION

The current research provided further, though partial, evidence for the gradient-shaped distribution of perseverance errors in the post-interruption context, as posited by the memory for goals (MFG) model (Altmann et al., 2014; Trafton et al., 2011). In the post-interruption context, one-step perseverations were statistically more frequent than two-step perseverations. Also, in the baseline context, skipping one step was numerically more frequent than skipping two steps, but the difference did not reach statistical significance. The same pattern of one-step error being more frequent than the two-step appeared in the anticipation errors, although the effect was statistically significant only in the baseline context. These results are similar to data gathered in the UNRAVEL experiments (Altmann et al., 2014; Trafton et al., 2011).

Furthermore, the current study confirmed the asymmetry between perseveration and anticipation gradients in the post-interruption context. After the interruption occurred, participants tended to repeat the last step that they had performed in the procedure statistically more often than skipping the step ahead. The opposite asymmetry occurred in the baseline context, where anticipation errors were statistically more frequent.

To sum up, in terms of sequence error distributions, the outcomes of the WINDA task research are in line with the results obtained by Altmann et al. (2014; Trafton et al., 2011).

Analysis 4. Reliability of Sequence Errors

In this analysis, we focused on reliability analyses in order to test the potential of the procedure for future individual differences research. We assessed the reliability of internal consistency using Cronbach's α with sequence errors in Blocks 1–4 as indicators. The reliability estimate was 0.72. These results are in line with the outcomes of the original UNRAVEL data (0.54 and 0.72 in Experiments 1 and 2, respectively). Consistently, this shows that, similarly to the original task, the adapted procedure could be used for testing individual differences in sequential control.

GENERAL DISCUSSION

The aim of the current study was to develop the Polish version of the UNRAVEL task as a tool to measure placekeeping ability and to assess psychometric properties of the shortened language-specific procedure. To verify the usefulness of the WINDA tool, we re-enacted, to a large extent, the set of analyses completed by the authors of the original UNRAVEL procedure. The majority of the results in the current study paralleled those obtained by Altmann et al. (2014).

Validity and Reliability of the WINDA Procedure

The overall pattern of findings in the adapted WINDA study is analogous to Altmann et al.'s (2014) UNRAVEL results.

Firstly, our findings confirm that interruptions lead to an increased chance of resuming at the wrong step in a sequential task during a cognitively engaging activity.

Secondly, the interruption effect was constant for each of the tested rule types in the WINDA experiment. Differences in the level of difficulty of rules, indicated by the results of the nonsequence errors analysis, showed no effect on sequential performance.

Thirdly, the patterns of gradients and asymmetry in the proportions of sequence errors as a function of distance obtained in the current study are in line with previous results (Altmann et al., 2014; Trafton et al., 2011). In terms of sequence error distributions, the WINDA experiment provided partial evidence for the gradient-shaped distribution of perseverance errors. The error numbers decreased as distance increased in the post-interruption context. Immediately after the interruption, all participants tended to repeat the last step in the procedure significantly more often than going back two steps. The same pattern of one-step errors happening more frequently than two-step errors appeared in the anticipation errors for the baseline context. As to error distributions asymmetry, perseverations were significantly more frequent than anticipation in the post-interruption context. Conversely, in the baseline context the direction of errors was reversed, with statistically more +1 than −1 errors.

Lastly, the reliability estimates of Cronbach's α at 0.72 confirmed that the adapted procedure, much like the original UNRAVEL task, could be used for testing individual differences in placekeeping performance. Furthermore, as Altmann et al. (2014) argue, a simpler version of the UNRAVEL task could be more eligible to characterize developmental and neuropsychological deficits in sequential control. This makes WINDA a valid candidate for such tasks.

To sum up, the results obtained in our study suggest that particular rules used in the UNRAVEL task, their type and number, and consequently, the acronym itself (defined as a set of rules), could be exchanged for another one (e.g., WINDA) without compromising the procedure as a tool to measure sequential processing. This opens possibilities for creating different versions of the task (characterized by different levels of difficulty) targeted at specific subject groups.

Study Limitations and Future Directions

Analyses of errors conducted during the process of data analysis of the WINDA results took into account sequence errors and nonsequence errors. The first error type occurs when the answer provided by the subject relates to the correct rule but the answer itself is wrong (i.e., choosing w instead of m for a lowercase letter). The second type describes a situation in which the subject lost track of the order of rules and provided an answer relating to the wrong rule. However, it is worth noting that when such a classification is used, sequence errors include two situations: (a) when the answer given refers to the wrong rule in the order and the answer itself is wrong, and (b) when the answer refers to the wrong rule but the answer itself is correct regarding the stimuli presented on the screen. Suppose a situation in which the appropriate rule at a particular moment is *I*, the stimulus on the screen includes *1* and *b*, and the subject gives the answer *m*. This answer is classified as a sequence error, and the correctness of the answer (defined as a nonsequence error) is not analyzed, as the statistics for nonsequence errors only take into account the situations when the answer matched the correct sequence step (in this example, the answers *i* and *r* for the *I* step). In future studies, the analyses of nonsequence errors should include both sequence errors and correct answers. It would be interesting to verify what happens to nonsequence errors when a sequence error was committed, that is, whether a sequential error also leads to a disturbance in remembering the rule in question, or whether a sequence error does not necessarily lead to simultaneous nonsequential errors. It would be especially interesting to compare these error types in order to gain a better insight into the nature of sequential processing, taking into account that Altmann et al. (2014) suggest that sequential processing might be a special type of cognitive ability.

FOOTNOTES

[1] Four gradient effects consist of two |2| vs. |1| comparisons for perseverations and anticipations in two contexts (post-interruption vs. baseline).

REFERENCES

Altmann, E. M., & Gray, W. D. (2008). An integrated model of cognitive control in task switching. *Psychological Review, 115*, 602– 639. doi:10.1037/0033-295X.115.3.602

Altmann, E. M., Trafton, J. G., & Hambrick, D. Z. (2014). Momentary interruptions can derail the train of thought. *Journal of Experimental Psychology: General, 143*, 215–226. doi:10.1037/a0030986

Altmann, E. M., Trafton, J. G., & Hambrick, D. Z. (2017). Effects of interruption length on procedural errors. *Journal of Experimental Psychology: Applied, 23*, 216–229. doi:10.1037/xap0000117

Burgoyne, A. P., Hambrick, D. Z., & Altmann, E. M. (in press). Placekeeping ability as a component of fluid intelligence: Not just working memory capacity. *American Journal of Psychology.*

Dykiert D., Der G., Starr J. M., & Deary I. J. (2012). Age differences in intra-individual variability in simple and choice reaction time: Systematic review and meta-analysis. *PLoS One 7*: e45759. doi:10.1371/journal.pone.0045759

Folstein, M., Folstein, S. E., & McHugh, P. R. (1975). "Mini-Mental State:" A practical method for grading the cognitive state of patients for the clinician. *Journal of Psychiatric Research, 12*, 189–198. doi:10.1016/0022-3956(75)90026-6

Hambrick, D. Z., Altmann, E. M., & Burgoyne, A. P. (2018). A knowledge activation approach to testing the circumvention-of-limits hypothesis. *American Journal of Psychology, 131*, 307–321.

Miyata, Y., & Norman, D. A. (1986). Psychological issues in support of multiple activities. In: D. A. Norman & S. W. Draper (Eds.), *User centered system design: New perspectives on human-computer interaction* (pp. 265–284). Hillsdale, NJ: Erlbaum.

Trafton, J. G., Altmann, E. M., & Ratwani, R. (2011). A memory for goals model of sequence errors. *Cognitive Systems Research, 12*, 134–143. doi:10.1016/j.cogsys.2010.07.010

Weiss, D., & Miłkowski, M. (2013). Morfologik: Morfologik 2.0 PoliMorf [online]. Retrieved from http://morfologik.blogspot.com/2013/03/morfologik-20-polimorf.html

Woods, D. L., Wyma, J. M., Yund, E. W., Herron, T. J., & Reed, B. (2015). Factors influencing the latency of simple reaction time. *Frontiers in Human Neuroscience, 9*, 131. doi:10.3389/fnhum.2015.00131

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APPENDIX: DESCRIPTIVE STATISTICS FOR ERROR RATES AND RESPONSE TIMES

	M	*SD*	Skewness	Kurtosis
Sequence error rate [post-interruption, block 1]	0,17	0,26	1,05	-0,06
Sequence error rate [baseline ,block 1]	0,05	0,08	1,75	2,37
Nonsequence error rate [post-interruption, block 1]	0,25	0,30	0,71	-0,44
Nonsequence error rate [baseline, block 1]	0,16	0,13	0,93	0,83
Response time [post-interruption, block 1]	0,07	0,64	0,41	-0,37
Response time [baseline, block 1]	-0,04	0,27	0,39	-0,27
Sequence error rate [post-interruption, block 2]	0,16	0,28	1,54	1,48
Sequence error rate[baseline, block 2]	0,05	0,09	2,54	7,14
Nonsequence error rate [post-interruption, block 2]	0,29	0,33	0,72	-0,54
Nonsequence error rate [baseline, block 2]	0,17	0,13	0,87	0,50
Response time [post-interruption, block 2]	-0,07	0,54	0,85	0,84
Response time [baseline, block 2]	-0,21	0,21	0,57	0,72
Sequence error rate [post-interruption, block 3]	0,18	0,30	1,53	1,24
Sequence error rate [baseline, block 3]	0,06	0,09	1,63	2,80
Nonsequence error rate [post-interruption, block 3]	0,29	0,36	0,80	-0,63
Nonsequence error rate [baseline, block 3]	0,18	0,13	0,35	-0,63
Response time [post-interruption, block 3]	-0,24	0,54	1,12	1,22
Response time [baseline, block 3]	-0,25	0,24	0,81	0,61
Sequence error rate [post-interruption, block 4]	0,19	0,31	1,44	0,91
Sequence error rate [baseline, block 4]	0,04	0,07	1,64	2,14
Nonsequence error rate [post-interruption, block 4]	0,29	0,34	0,72	-0,57
Nonsequence error rate [baseline, block 4]	0,17	0,13	0,89	0,64
Response time [post-interruption, block 4]	-0,21	0,66	1,17	1,14
Response time [baseline, block 4]	-0,39	0,20	0,68	-0,01