2004

The effects of readback on a spatial navigation task

Amy Louise Lynn
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

Recommended Citation

Lynn, Amy Louise, "The effects of readback on a spatial navigation task" (2004). *Master's Theses*. 2548.
DOI: <https://doi.org/10.31979/etd.rrmb-f3h4>
https://scholarworks.sjsu.edu/etd_theses/2548

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

THE EFFECTS OF READBACK ON A SPATIAL NAVIGATION TASK

A Thesis

Presented to

the Faculty of the Department of Psychology

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

by

Amy Louise Lynn

May 2004

UMI Number: 1420430

Copyright 2004 by
Lynn, Amy Louise

All rights reserved.

INFORMATION TO USERS

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleed-through, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

UMI[®]

UMI Microform 1420430

Copyright 2004 by ProQuest Information and Learning Company.

All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

© 2004

Amy Louise Lynn

ALL RIGHTS RESERVED

APPROVED FOR THE DEPARTMENT OF PSYCHOLOGY

Dr. Kevin Jordan
Psychology Professor, San Jose State University

Dr. Rahul Dodhia
Senior Research Associate, NASA Ames Research Center

Dr. Ronald Rogers
Psychology Professor, San Jose State University

APPROVED FOR THE UNIVERSITY

ABSTRACT

THE EFFECTS OF READBACK ON A SPATIAL NAVIGATION TASK

by Amy Louise Lynn

When pilots receive an instruction from Air Traffic Control, they are expected to repeat the instruction, allowing the controller to verify it. Errors in carrying out these instructions are hypothesized to be caused by interference from the repetition. Participants heard messages instructing them to move within a 2-dimensional depiction of a 3-dimensional space consisting of four stacked grids displayed on a computer screen. Participants were asked both to orally repeat the instructions and follow them. Three groups were compared. Participants repeated the messages before, after, or while performing the manual movement. The number of words used in each instruction along with the number of instructions per message also varied within subjects. Messages containing more than three instructions led to error rates of more than 50%. Results suggest that interference did not occur in this study. However, interference or workload as causes of errors in manual performance cannot be ruled out.

ACKNOWLEDGEMENTS

I would like to take this opportunity to thank all of those who have been so supportive during my endeavor to complete my Master's degree. I have realized how truly blessed I am to have the friends and family that have supported me through this life-changing event. I would like to start by thanking Dr. Kevin Jordan for the opportunity to further my education and for his hard work with the San Jose State University Foundation. I sincerely appreciate your guidance in my academic endeavors. Also, thanks to Dr. Ron Rogers, your teaching style and sense of humor were much appreciated during such a stressful time. Thank you Dr. Immanuel Barshi for developing the paradigm for which my experiment fell under and for his passion in aviation research. Thank you for technical support from Wayne Stone, John Empey, and Lori Bonanno. A special thank you to Dr. Rahul Dodhia, I cannot thank you enough for all your time, support, encouragement, and wisdom. To Dr. Jon Holbrook, thank you for all of your coaching during Psychonomics and ISAP. Thank you to Dr. Jessica Nowinski, Dr. Yuri Tada, Audra Ruthruff, Kim Jobe, Sean Belcher, and especially my office mate, Jolene Bischoff. You have all been so encouraging, always providing wonderful feedback, and knowledge I will keep a lifetime. To my fellow graduate buddies, thanks for the study groups, sharing the fun times and the tears and thank you for not letting me quit! More than anyone else, I would like to thank my beloved Tom who has shown me unconditional love on a daily basis, has encouraged my dreams above his own, and has always believed in me. Finally, a special thanks to my mom and dad for their endless encouragement, love and support, and to my grandmother for her continual prayers.

TABLE OF CONTENTS

SECTION	PAGE
INTRODUCTION	1
Previous Studies	4
Current Study	8
Hypotheses	10
METHOD	11
Participants	11
Design	11
Materials.....	12
Procedure	12
RESULTS	16
Manual Movement Response.....	17
Oral Repetition Response.....	20
DISCUSSION	22
Future Study.....	25
Conclusion	28
REFERENCES	31
APPENDIXES	34
Appendix A. Human Subjects Approval Form.....	35
Appendix B. Consent Form	37
Appendix C. Experimenter's Instructions.....	39

Appendix D. Participant's Instructions.....	43
---	----

LIST OF TABLES

TABLE	PAGE
1. Examples of minimal and redundant wordiness at each of the one to six message lengths.....	14

LIST OF FIGURES

FIGURE	PAGE
1. Design for laboratory experiments.....	5
2. Means with standard errors of accuracy for condition and wordiness (minimal amount of words versus redundant words). Error bars represent plus or minus one standard error of the mean.....	18
3. Means for manual movement response for three conditions (MO, OM, and Simultaneous). Error bars represent plus or minus one standard error of the mean.....	19
4. Means in the oral movement condition of message length accuracy for three conditions (MO, OM, and Simultaneous). Error bars represent plus or minus one standard error of the mean	21
5. Interaction of wordiness and message length in the oral repetition response. Error bars represent plus or minus one standard error of the mean.....	23
6. These are predictions for a future study (this is for illustrative purposes only).....	29

The Effects of Readback on a Spatial Navigation Task

As a greater number of aviators take to the skies, it is more important than ever that clear communication exists between air traffic controllers (ATC) and pilots. Clearly, communication is critical and communication errors (e.g., during readback) exist. Readback is a key part of communication because it is the only opportunity for ATC to verify that the pilots are taking the appropriate action. Billings and Cheaney (1981) found that 73% of aviation safety reporting system (ASRS) reports contained evidence of problems in the transfer of information. Some of the issues include how many instructions are given in one transmission and the wordiness of each instruction. Here is an example of one such problem reported in an ASRS report:

The controller was very busy with aircraft on his frequency and we were expecting a climb clearance since our filed cruise altitude was 35,000 feet. It was at this point that our flight received a clearance to “two, five, zero.” I was the pilot flying and after the first officer read back the clearance as “two, five, zero” without stating “climb to” or “leaving two, three, zero for two, five, zero,” I started the climb. At 23,600 feet, ATC asked what our assigned altitude was. We restated ‘flight level two, five, zero.’ He said that was supposed to be a heading of two hundred and fifty degrees. He told us to descend to flight level two, three, zero immediately. I, as the pilot flying, disconnected the autopilot and descended to flight level two, three, zero. As I was doing this the TCAS II audio was stating, “traffic, descend, descend.”

Fortunately this error did not have serious consequences; however the report underscores the criticality of these problems. After the pilot's readback, ATC asked for clarification on the altitude, which lead to discovering a communication error. It is not clear though if the timing of readback (before, during, or after executing the controller's instructions) affects the pilot's ability to follow the instructions correctly. Not only is readback imperative for the communication between ATC and a pilot to verify that the correct aircraft is given the correct clearance, readback may also act as a rehearsal for the pilot before the navigational task is performed.

The environment in which ATC-pilot communication takes place is highly regimented due to the absolute importance of safety. Due to a variety of factors (some beyond pilots' control) such as weather, traffic, emergencies, and pilots' requests, ATC instructions are constantly amended. This dynamic environment also creates a unique language shared between ATC and pilots that fosters continuity. Controllers work as managers, managing traffic flow by giving the pilot an instruction or instructions to navigate through space. These instructions can become lengthy and complex.

Pilots fly filed route clearances, and depending on the type of operation, during preflight they consult either a Flight Service Station or company dispatch to decide which route they will be taking. Next, they file their planned route with flight services who pass the information on to ATC. At this time, the pilots receive clearance delivery that either confirms the route or amends it. Once a crew takes off, they communicate with different air traffic controllers depending on their location. Pilots can hear other pilots over the radio and can identify the location of other aircraft. This party-line communication

may create an understanding of where pilots are in relationship to their environment.

The pilot also receives necessary information from each instruction transmitted to them by ATC. The nature of each instruction is such that it may impact the development of a representation of the airspace and the representation of the pilots' aircraft within that space. Furthermore, more complex instructions (those that contain many elements) might impact the spatial representation while placing higher demands on working memory. For example, a typical transmission of three instructions from ATC might be, "Turn left heading three-five-zero, descend and maintain flight level two-niner-zero, reduce speed to point seven mach." In this transmission there are three instructions or propositions, which are independent of the number of words used to describe each message. In less complex transmissions only one instruction is given, such as those used during precision approach radar (PAR). Rather than "turn right five degrees," the instruction could be as short as, "right five." Emulating the ATC instructions, a participant in a laboratory experiment can be given a different number of instructions to evaluate working memory limitations. Therefore, each instruction is a new message, regardless of how many words are used to describe the instruction.

In some conditions (e.g., when controllers give urgent instructions or when the frequencies are congested), the pilot will read back and execute the instruction at the same time, or read back after execution. It is well established that repetition at encoding improves short-term memory (Ebbinghaus, 1885). This leads to the prediction that pilots should benefit from readback. In other words, readback provides an additional opportunity to rehearse the information. Conversely, repeating back the instructions

before execution might cause an interruption or interference (Roodiger & Schmidt, 1980). This is because reading back the instruction might interfere with the memory for the other instructions, and this results in a decrease in manual performance. Reading back the instructions after executing them would avoid this potential problem and would still provide ATC with the feedback they require, except when the instruction was misheard and executed incorrectly. If readback and execution happen at the same time there could be negative consequences to one or both tasks due to the interference of the performance of one task with the performance of the other (Anderson, 2000). Also, if one task is highly automatic, it is possible to do two tasks at the same time. For example, driving a car while talking is a common occurrence. However, if the demands of driving increase, the ability to carry on a conversation is diminished (Anderson, 2000).

Previous Studies

In order to investigate various communication concerns between pilots and ATC, Barshi (1997) developed a laboratory paradigm for studying readback errors. Participants navigated through a simulated space by following a series of messages for moving within a grid of four 4x4 matrices stacked on a computer screen, one on top of another, representing a 3-dimensional space (see Figure 1). They heard similar instructions to those given to pilots by ATC. Analogous to the action of a pilot, participants repeated the instructions aloud (oral repetition responses), and then followed the messages by clicking a computer mouse to navigate within and between the matrices on the computer screen (manual movement responses).

Figure 1. Design for laboratory experiments

Using this paradigm, Barshi and his colleagues have examined the effects of message length (i.e., one to six instructions) and wordiness of the message (i.e., whether or not the messages contain redundant elements) on people's ability to accurately perform navigation instructions (Barshi, 1997, 1998; Barshi & Healy, 2002; Schneider, Healy, & Barshi, 2001). A consistent finding was that the biggest drop in both oral and manual performance occurred between message length three and four. Although participants had equal practice time, when there were three messages the error levels were near zero, but when there were four messages error levels were about 50%. The errors were defined as "all or nothing performance." In other words, in both the oral and manual movement response, if a participant responded incorrectly to any of the possible one to six messages, the entire response was counted wrong.

When message length was controlled, participants performed better on the readback (oral responses) with minimal wordiness (e.g., left two, down one, forward one), rather than with more complex messages (e.g., turn left two squares, climb down one level, move forward one step). Although the study reported clear effects of wordiness and message length on both manual and readback performance, it remained important to study the mechanism that produced the performance decrements.

Barshi and colleagues postulated that manual performance could be affected by readback. Recalling the instructional elements during readback could interfere with recall for the instructional elements for manual movement (Hadley, Healy, & Murdock, 1992). However, they were unable to determine whether manual performance was affected by the content of the readback task or simply any kind of verbalizing. This

prompted Leonard's (n.d.) investigation of the effects of readback on manual movement by assessing participants' responses in three conditions.

Leonard's study included a repeat condition in which the participant heard the instructions, read back the instructions, and then moved (as in Barshi & Healy, 2002). In a second, suppression condition, while hearing the instructions participants said the word "the" repeatedly and then moved. In a third, silent condition the participant heard the instructions and then moved. In this study, only manual movement performance was measured. The data showed that participants' performance was worse in the repeat and suppression conditions than in the silent condition. There was no difference between the repeat and suppression conditions. These results suggested that performing a second task, such as verbalizing, may hurt performance on the subsequent manual movement task. With regard to wordiness, performance was better in the suppression and silent conditions with more complex messages. This could be due to the fact that it took more time for the computer to deliver the longer complex messages to the participant and therefore required more time to process those messages. The effect of message length was replicated, and as in previous studies, performance decreased as message length increased.

Although Leonard's study indicated that readback affected the manual movement response, it failed to provide an explanation for why participants performed more poorly in the two verbal conditions. Rehearsal can strengthen the representation of items in memory, so it is surprising that the participants performed poorly in the repeat condition.

However, repeating the message may act as an interpolated task, causing a decrement in performance due to interference.

Barshi and Healy (2002) postulated that there is an interdependence between spatial and verbal responses. They tested participant's verbal recall while navigating in two different types of space (2D vs. 3D). Although the commands were the same in both conditions, the nature of the spatial responses changed. Participants in the 2D condition made fewer errors than those in the 3D for both the oral and manual responses. This suggested that spatial responses affected verbal responses. On the other hand, Leonard's study suggested that verbal responses affected the spatial responses. The current study attempts to determine, within a single context, whether the interdependence of spatial and verbal response is symmetrical. That is, we seek to determine whether spatial response affects a verbal response and whether verbal responses affect spatial responses.

Current Study

Performing the wrong sequence of motor tasks may be due to incorrect recall of the sequence. Even if the correct sequence had been encoded, the fact that verbalizing occurs throughout the sequence may cause the interference. This process is similar to the one described by Tulving and Arbuckle (1963) of output interference for verbal recall. In their experiment, participants studied a list of paired associates. One member of each pair was then given in the recall test and the subjects had to recall the associated item. They found that as more pairs were recalled, the less likely later pairs would be remembered. We postulate that a similar mechanism could cause recall of verbal items to

decrease performance of a motor task. Conversely, the act of performing the motor task could cause a decrease in the verbal task.

In order to determine whether the decrement in manual performance in the repeat and suppression conditions of Leonard's (n.d.) study was due to this same type of interference, we conducted a study in which we systematically manipulated the temporal relationship between readback and the manual response. If interference caused the decrement, the question is why. It could be that as participants repeated back one command, the verbalization interfered with their memories for the command they had yet to follow. Thus, we included one condition in which the participant heard the instructions, read them back, and then moved (as in Leonard's study, oral response then manual response; OM condition) and another condition in which the participant heard the instructions, moved, and then read them back (manual then oral; MO condition). Finally, we included a third condition in which the participant heard the instructions and performed the readback and movement simultaneously (simultaneous condition). If Leonard's finding of a poor manual response in the repeat condition was due to interference, then to insure there was no interference, we asked the participants in the MO condition to perform the movement before reading back. We expected the performance in the manual response to improve.

In the present study, the primary purpose was to investigate interference. We also replicated a portion of Barshi's (2002) study by including wordiness (redundant or minimal words) and message lengths (1-6) to determine if those variables interacted with

the condition variable described above. We measured the impact of these variables by using accuracy of both the oral repetition response and manual movement response.

Hypotheses.

We hypothesized that the oral response interferes with the subsequent manual response. Therefore, participants' manual movement response would be better in the MO condition than the OM condition. In the OM condition, reading back may interfere with the later manual response, whereas in the MO condition, the manual response has been made before any readback occurs. Therefore, it is reasonable to expect the participants in the MO condition to have better manual performance because the movement response comes first. We also expected manual performance in the simultaneous condition to be poorer than the other conditions due to performing two tasks at once.

Since we have no evidence from past studies or theory to suggest that order of the tasks should affect oral response, we hypothesized that oral performance should be the same in the MO and OM conditions. However, if we do observe the participants performing better on the oral repetition response in the OM than the MO condition, that may be because readback is the first response and comprehending the meaning of the spatial instruction does not interfere with repeating back that message. We also hypothesized that readback performance in the simultaneous condition would be poor because of performing two tasks at once.

We expected to find the same results as Barshi et al. (2002) and Leonard (n.d.) regarding wordiness and message length. We predicted that participants would perform better in both oral and manual measures with minimal words than with redundant words

because there is less to remember. Lastly, we hypothesized a decrease in performance with an increase in the number of messages with the largest decrement after three messages.

Method

Participants

Thirty-six introductory psychology students from San Jose State University participated in the current study. The participants had normal or corrected-to-normal vision and hearing and were native English speakers. The participants were also right-handed because the equipment was configured for a right-handed participant. The volunteers received class credit for participating and were treated in accordance with the guidelines for the use of human subjects specified by the university.

Design

The experiment employed a mixed-factorial design. There were three independent variables and two dependent variables. The first independent variable was condition. Three conditions were compared in which participants listened to the set of instructions and a) repeated the instruction and then performed movement responses (oral then move; OM), b) performed movement responses, then repeated instructions (move then oral; MO), or c) repeated instructions and performed movement responses simultaneously (oral and move at the same time; simultaneous). Out of the 36 participants, 12 were assigned randomly to each of these three conditions. A second independent variable was number of messages. This within-subjects variable was composed of six levels, each with an instruction containing from 1 to 6 messages. The

third independent variable was wordiness of the proposition. The proposition was either minimal (e.g., left two) or redundant (e.g., turn left two squares). This variable was also manipulated within-subjects. Accuracy for both manual movement and oral repetition responses were evaluated as dependant variables.

Materials

The verbal stimuli were digitized and presented through the computer's audio system. Participants used a mouse to execute the action of clicking a single 1 x 1 square within and between the four 4 x 4 matrices on a full page 21 cm x 28 cm display monitor with the 28 cm side vertically positioned. The participants sat approximately 45 cm from the computer monitor with one hand on the computer mouse, clicking as they made their move. Their verbal responses were recorded on an analog tape recorder.

Procedures

In our laboratory task, the experimenter followed strict guidelines (See Appendix A) for explaining the procedures to the participant and the participant was then given detailed written instructions to read (see Appendix B). Participants were instructed to move within a 3-dimensional model (to show their understanding of the procedure). Next, the participants performed 12 practice trials with the experimenter giving feedback on both the oral and manual responses. If the participant performed the task flawlessly, the feedback given was "good," or "correct." If the participant made errors during the practice session, the feedback involved how to correct the errors. After the practice trials, the experimenter left the room and the participants were ready to begin. During both the practice and experiment trials, participants saw on the computer screen four grids,

stacked one above the other (see Figure 1) and were told that the grid represented a three-dimensional space. Each grid was made of 16 squares (4x4). The starting position (which stayed constant across all subjects) was highlighted. While turning (right or left) and moving (forward or back) on the screen, participants always stayed on the same grid. To climb, they went to a different grid (up or down). To follow the instructions, they clicked the computer mouse in the appropriate places on the grids. Because there were four 4x4 grids, the numbers in the instructions were limited to one, two, and three; that is, they could never turn, move, or climb more than 3 squares. Also from any position, there were a limited number of moves a participant could make without “falling off” the grid. The instructions were set so they would never fall off. The wording of the messages remained constant. The instructions followed the structure: turn (left/right; one/two/three) squares, climb (up/down; one/two/three) levels, move (forward/back; one/two/three) steps. Therefore, turning was always associated with the term squares, climbing with levels, and moving with steps for the redundant condition only. Participants were given messages of six different lengths, ranging from one to six messages, with the messages varying in their wordiness. The instructions either included redundant four-word statements (e.g., “turn left two squares”) or they included minimal two-word statements (e.g., “left two”) examples can be seen in Table 1.

Table 1.

Examples of minimal and redundant wordiness at each of the one to six message lengths.

Message lengths	Minimal Wordiness	Redundant Wordiness
One	Left two.	Turn left two squares.
Two	Left two.	Turn left two squares.
	Down one.	Climb down one level.
Three	Left two.	Turn left two squares.
	Down one.	Climb down one level.
	Forward one.	Move forward one step.
Four	Left two.	Turn left two squares.
	Down one.	Climb down one level.
	Forward one. [*]	Move forward one step.
	Right three.	Turn right three squares.
Five	Left two.	Turn left two squares.
	Down one.	Climb down one level.
	Forward one.	Move forward one step.
	Right three.	Turn right three squares.
	Up two.	Climb up two levels.
Six	Left two.	Turn left two squares.
	Down one.	Climb down one level.
	Forward one.	Move forward one step.
	Right three.	Turn right three squares.
	Up two.	Climb up two levels.
	Back three.	Move back three steps.

As noted above, three groups were compared: The first group heard the instructions, repeated them, and made the appropriate movements (OM). The second group heard the instructions, made the appropriate movement (MO), and then repeated the instructions; and the third group heard the instructions, then repeated and made the appropriate movements at the same time (simultaneous). In the OM and MO conditions, the participant clicked a button labeled DONE after their first response (oral or manual) and again clicked DONE after the second response (oral or manual). In the simultaneous condition, immediately after hearing the instructions, the participant moved and read back at the same time and then clicked the DONE button. During the manual movement process, the participants were reminded to click on every square they passed, so two squares would equal two clicks, three squares would equal three clicks. However, when climbing, participants only needed to click on their target square on the level either above or below, and not literally on every square they passed.

Participants' verbal responses were recorded electronically during the experiment. Later, the participants' responses were transcribed verbatim to ensure a strict measure of accuracy. If participants said a word that was not part of the instructions (i.e., over), that word was replaced with an X. Also, if they said "climb" or other words such as "move" or "over," they were replaced with an "X" only if the other directional word was not given. However, if the participant said "right," "right one" (RR1), it was still coded as R1 because the axes are fixed (that is, they can't turn around in a circle by continuing to turn right); therefore, there was not much room for confusion. Also, the sequence in which they repeated the instructions and made the appropriate movements was strictly

enforced. In the simultaneous condition, both responses had to be made at the same time to be scored as correct.

In other words, if they were to repeat back and make the move at the same time, the transcribers listened very carefully to insure they heard clicking at the same moment the participant was speaking. If the participant did not click and speak at the same time, the participant's data was omitted. There were three occasions in which the data was omitted because it was apparent during transcription that the participants were not moving and repeating back at the same time.

For each of the three conditions (OM, MO, and simultaneous), the participants completed seven replications of the 12 unique combinations of six messages and two levels of wordiness for a total of 84 trials. The order of presentation of the 12 combinations of message lengths and wordiness was randomized within each block. The first block of trials was considered practice and was not analyzed. Each trial lasted approximately 30 seconds. The entire experiment required approximately 45 minutes.

Results

Separate 3 (Condition: MO, OM, and simultaneous) by 2 (Wordiness of proposition: minimal and redundant words) by 6 (Message lengths: 1-6) mixed analyses of variance (ANOVAs) were conducted on the manual movement responses and on the oral responses: Condition was a between-subjects factor in both analyses. Because the scoring method for both responses required that they be correct for all instructions, data entry options were either correct or incorrect. The participant had to correctly repeat back and move exactly according to the commands. If any part of the instruction was

repeated back incorrectly (the wrong order or wrong words used), the entire response was marked incorrect. Similarly, if any movement was not correct or was out of order, the entire response was considered an error. The means for all conditions averaged across all message lengths are shown in Figure 2. The dependant variables, oral repetition response and manual movement response, were highly correlated ($r = 0.93$), indicating correct oral responses were associated with correct manual movement responses.

Manual Movement Response

There was no main effect of condition for the manual movement response $F(2, 33) = .23, p = .80$. Therefore our hypothesis that the oral response interferes with the manual response did not hold. The non-significant main effect also shows that contrary to the hypothesis that performing two tasks at once would lead to worse performance in both the oral and manual response, movement responses in the simultaneous condition were no worse than MO or OM conditions.

The ANOVA also did not show a main effect of wordiness. Therefore redundant messages did not result in better performance (although there was a marginally significant interaction with number of messages, $F(5, 165) = 2.1, p = .06$). As can be seen in Figure 3, there was a main effect of message length. As the number of messages increased, accuracy decreased, $F(5, 165) = 281.72, p < .01$. Additionally, there was a significant interaction of condition with message length, $F(10, 165) = 2.1, p < .05$. Figure 3 shows that there might be differences among the condition at message lengths 2 and 3.

This interaction was examined further. Specifically, MO ($M = 0.79$) had poorer performance at message length 2 than OM ($M = 0.89$) and simultaneous ($M = 0.90$) but

Figure 2. Means with standard errors of accuracy for condition and wordiness (minimal amount of words versus redundant words). Error bars represent plus or minus one standard error of the mean.

Figure 3. Means for manual movement response for three conditions (MO, OM, and Simultaneous). Error bars represent plus or minus one standard error of the mean.

better performance at message length 3, ($M = 0.76$) than OM ($M = 0.66$) and simultaneous ($M = 0.58$). Since there was no main effect of wordiness, the data were collapsed across that variable and a 3 (conditions) by 2 (message lengths) mixed ANOVA was conducted on manual movement responses for message length 2 and 3. There was a main effect of condition, $F(2, 33) = 11.83, p < 0.01$. This was a Bonferroni test, so even with the correction for alpha, the difference is significant.

Oral Repetition Response

There was no main effect of condition on the oral repetition accuracy, $F(2, 33) = .95, p = .40$. Therefore, we failed to reject our hypothesis that oral responses would be the same in both MO and OM conditions. However, a failure to reject the null hypothesis does not constitute strong evidence that the verbal and spatial representations affect each other. As in the manual performance, the non-significant main effect does not go against the notion that there could be an interdependence between spatial and verbal representations. Again, due to the non-significant main effect, our hypothesis that the simultaneous condition would be worse than the other two conditions did not hold (see Figure 4).

There was a significant main effect of wordiness, $F(1, 33) = 4.5, p = .04$. Performance was better with minimal words in the oral repetition response. There was a main effect of message length in the oral response $F(5, 165) = 66.9, p < .01$. This supports the hypothesis that as message length increases, accuracy decreases. Also, there was a significant interaction of wordiness with message length, $F(5, 165) = 11.95, p < .01$.

Figure 4. Means in the oral movement condition of message length accuracy for three conditions (MO, OM, and Simultaneous). Error bars represent plus or minus one standard error of the mean.

With 3 messages, the mean for redundant words was 0.80 and the mean for minimal words was 0.59, but for all other message lengths, there was no difference between minimal and redundant words (see Figure 5). Six t-tests with a Bonferroni correction for alpha revealed that wordiness was significantly different at message length 3, $p < 0.008$, and not significantly different at any other message lengths.

Discussion

The purpose of this study was to investigate if readback from pilots to ATC interferes with the pilot's flying performance. Barshi and Healy (2002) concluded that readback could interfere with the manual performance. These findings led to Leonard's (n.d.) investigation into the type of interference that affected the manual response. She found that verbal interference did occur, however it was not clear why participants performed worse in the two verbal tasks. The current study also examined whether the decrease in manual performance was due to interference. We sought to determine whether performing the oral repetition response would interfere with recall for the messages to be executed for the manual movement response. We manipulated timing of readback (before, during, or after executing the controller's instruction). There were three important findings. First of all, there was no evidence of interference by the verbal task on the manual performance except at message lengths 2 and 3 in which there was a significant interaction. More specifically, the order in which the oral and manual tasks were performed made no difference in the accuracy of the oral and manual outcome except at message lengths 2 and 3. This could simply be an anomaly or it may be that

Figure 5. Interaction of wordiness and message length in the oral repetition response.

Error bars represent plus or minus one standard error of the mean.

more could be investigated around message length 3. Interestingly it is after message length 3 that a large drop in performance occurs. Because the participants in the MO condition performed better at message length 3 than those in OM and Simultaneous conditions, maybe manual performance is better when there is no interpolated task for this message length. From message length 4 on, all conditions are extremely low in accuracy. Furthermore, we did find, as in the Barshi study, an effect of wordiness on the accuracy of the oral response and an effect of message length on both the manual and oral performance.

The first hypothesis was that in the manual movement response, participants would perform worse in the OM condition than in the MO condition, reflecting verbal interference. We tested to see if the verbal task influenced the subsequent manual task. We found no difference in the manual movement response between the MO and OM condition, except at message lengths 2 and 3, suggesting that interference from readback is not a factor in manual performance. In fact, the manual performance results were the same for all three conditions.

In the oral repetition response (participants repeated back what they heard from ATC; before, during, or at the same time as making their manual response) the findings were similar. We found no difference between the MO and OM conditions. In the simultaneous condition, we found participants performing two tasks at the same time performed as well as those who performed them sequentially. This result was true for both the manual and oral responses. Either the tasks did not draw on the same cognitive resources, or they were easy enough that they did not need to compete for resources.

Any conclusions based on null results should be interpreted with caution. It is possible that we did not find interference because our measure was not sensitive enough to detect an effect. Possibly, this study may have needed more participants in order to produce enough statistical power.

However, it could truly be that the verbal information was not affected by the manual performance in the MO condition. Similarly, it could be that there is no interference from the verbal task on the manual response. Some researchers, such as Shah & Miyake (1996), suggest that language and spatial processes are independently supported; therefore performance in one modality should not cause interference on another modality. Their study found that spatial measures correlate with spatial, not verbal, ability and verbal measures correlate with verbal, not spatial, ability, giving further evidence of the separability for spatial thinking and language processing.

However, Barshi's (2002) study found readback interfered with a manual task. Leonard (n.d.) tried to determine if there was a specific type of oral response (readback or another verbal task) that contributed to interference. She found that both readback and an unrelated verbal task affected manual performance, but could not determine the characteristics of the verbal task that caused the interference. Given these diverse findings, a new study is needed to resolve the issue of whether there is interference between tasks and what the nature of that interference might be.

Future Study

One purpose of the future study is to examine the following questions: if interference does cause a decrement in motor performance, what is the nature of this

interference? Conversely, if verbal interference does not cause a decrement, what was the cause of the decrement in manual performance observed by Barshi et al. (2002) and Leonard (n.d.)?

Yeh and Wickens (1988) suggest that greater resources are used when demands on working memory are increased. Workload can be defined as the amount of working memory that is being taken up by current tasks (Tomprowski, 2003; Yeh & Wickens, 1988). In Leonard's study, the conditions with readback or suppression would have higher workload than the silent condition. One hypothesis is that workload was a factor in Leonard's study, because performance was better in the silent condition (with no interpolated task), than in the readback and repeat condition, both of which had interpolated tasks. Wickens (1984) proposes a multiple resource theory to describe how the allocation of resources across various modalities produces an increase in workload, resulting in a decrease in performance. For example an interpolated verbal task prior to completion of a primary verbal task would produce an increase in workload. Furthermore, verbal repetition should not affect a primary task in another modality, such as a motor response. Therefore, workload would be lower for a situation such as verbal readback followed by the motor task of executing an ATC message. Finally, an interpolated motor task could affect motor response by increasing workload.

In contrast to this theoretical prediction, Barshi et al. (2002) and Leonard (n.d.) found that verbal repetition, whether or not it was related to the motor response, decreased the accuracy of the motor response. One of Schneider, Healy, and Barshi's arguments was that performance drops because of output interference (Broadbent, 1958;

Schneider, Healy, and Barshi, 2003). That is, recalling the response would interfere with the manual response.

In order to examine the contributions of workload and output interference to a decrement in the accuracy of the motor response, the following study is proposed. First, a baseline that replicates Leonard's Silent condition will be established.

- Silent without delay: participants sit quietly while hearing an ATC command and then immediately perform the movement (resources are used for one task).

After the baseline study, a study will be conducted using a 2 X 2 factorial design investigating relevant versus irrelevant information and verbal versus motor interference. The two factors of this design have two levels each: 1) Interpolated Task Type: Verbal and Motor, and 2) Output: Relevant and Irrelevant.

- 1) Verbally repeat Relevant information: participants hear ATC, repeat the command aloud, and then perform the movement.
- 2) Verbally say Irrelevant information: participants hear ATC, perform a verbal task that is unrelated to the command (e.g., counting down from an integer), and then perform the movement.
- 3) Motor task with Relevant information: participants hear an ATC command, "writeback" the commands on paper, and then perform the movement.
- 4) Motor task with Irrelevant information: participants hear an ATC command, perform an unassociated (write on a paper a countdown in 3s). The motor task would have to be difficult enough that there would be no chance for rehearsal.

These four conditions would be between-subjects and time constant (all durations of the interpolated task should be the same).

To investigate how much interference and workload contribute to the decrease in manual performance, each of the above conditions (Verbal Relevant, Verbal Irrelevant, Motor Relevant, and Motor Irrelevant) would need to be compared to the baseline condition (Silent condition).

Based on the empirical studies (Schneider, Healy, and Barshi, 2002; Leonard, n.d.) we expect motor performance after the interpolated verbal task to drop in both the Relevant and Irrelevant conditions because of output interference (Schneider, Healy, and Barshi, 2003). Furthermore, considering multiple resource theory, we would expect to see motor performance after the motor interpolated task to drop (compared to the baseline) because of higher workload imposed by sharing resources within a modality. We would not only expect to see a drop in motor task compared to the baseline, but we would also expect the biggest drop to be in the Relevant motor task due to workload (see Figure 6).

The experiment would also include the wordiness factor (minimal and redundant) as well as the message length factor (2-5, since floor and ceiling effects are found at levels 1 and 6). These two factors would be within-subjects and would be a replication of previous studies.

Conclusion

This study showed that readback did not have deleterious effects on manual performance, suggesting that the current closed-loop (read/readback/verify) procedure

Figure 6. These are predictions for a future study (this is for illustrative purposes only).

should be retained. As the anecdote in the introduction shows, the current procedure is effective in catching errors.

However, other studies (Barshi et al., 2002; Leonard, n.d.) have suggested that an interpolated task such as readback can negatively affect manual performance. The current study was not able to unequivocally show that output interference was the determinant for the decline in the manual performance in previous research. In order to investigate if workload could have caused the decrease in manual performance, an additional study was proposed in this paper to help answer these questions by systematically controlling the factors that might decrease manual performance.

Answers to this research question are important to alleviate errors in ATC-pilot communication. If this communication can occur more efficiently and accurately, it should reduce radio congestion, which is desirable in a world in which airwaves are getting more congested every day. A very important by-product of this is that airlines can operate more safely and efficiently.

References

- Anderson, J. R. (2000). *Cognitive Psychology and its Implications*. New York: Worth Publishers.
- Barshi, I. (1997). *Effects of linguistic properties and message length on misunderstandings in aviation communication*. Unpublished doctoral dissertation, Department of Linguistics, University of Colorado, Boulder.
- Barshi, I. (1998). *The effects of mental representation on performance in a navigation task*. Unpublished doctoral dissertation, Department of Psychology, University of Colorado, Boulder.
- Barshi, I., & Healy, A. F. (2002). The effects of mental representation on performance in a navigation task. *Memory & Cognition*, 30, 1189-1203.
- Billings, C. E., & Cheaney, E. S. (1981). The information transfer problem: summary and comments. In C. E. Billings (Ed.), *Information Transfer Problems in the Aviation System* (Technical Paper, NASA-TP-1875). Moffett Field, CA: NASA Ames Research Center.
- Broadbent, D. E. (1958). *Perception and communication*. New York: Pergamon.
- Ebbinghaus, H. (1885). Retention as a Function of the Number of Repetitions. In *Memory: A contribution to experimental psychology* (chap. 6). Retrieved from <http://psychclassics.yorku.ca/Ebbinghaus/memory6.htm>.
- Hadley, J. A., Healy, A. F., & Murdock, B. B. (1992). Output and retrieval interference in the missing-number task. *Memory & Cognition*, 20, 69-82.

- Leonard, A. (n.d.). The Effect of Readback and Articulatory Suppression on Performance in a Navigation Task. Unpublished master's thesis, University of Colorado, Boulder.
- Roediger, H. L. III. & Schmidt, S. R. (1980). Output interference in the recall of categorized and paired-associate lists. *Journal of Experimental Psychology*, 6, 91-105.
- Schneider, V. I., Healy, A. F., & Barshi, I. (2001, November). *The relationship between verbal and spatial representations of navigation instructions*. Poster session presented at the annual meeting of the Psychonomic Society, Orlando, FL.
- Schneider, V. I., Healy, A. F., & Barshi, I. (2003). *Effects of instruction modality and readback on accuracy in following navigation commands*. Manuscript submitted for publication.
- Shah, P., & Miyake, A. (1995). The separability of working memory resources for spatial thinking and language processing: An individual differences approach. *Journal of Experimental Psychology: General*, 125, 4 -27.
- Tomprowski, P. D. (2003). Performance and perceptions of workload among young and older adults: Effects of practice during cognitively demanding tasks. *Educational-Gerontology*, 29, 447-466.
- Tulving, E. & Arbuckle, T. Y. (1963). Sources of intratrial interference in immediate recall of paired associates. *Journal of verbal learning and verbal behavior*, 1, 321-334.

Wickens, C. D. (1984). *Engineering psychology and human performance*. Columbus, OH: Charles E. Merrill Publishing Company.

Yeh, -Yei -yu & Wickens, C. D. (1988). Dissociation of performance and subjective measures of workload. *Human-Factors*, 30, 111-120.

Appendixes

Appendix A

Human Subjects Approval Form

San José State
UNIVERSITY

**Office of the Academic
Vice President**

**Associate Vice President
Graduate Studies and Research**

One Washington Square
San José, CA 95192-0095
Voice: 408-283-7500
Fax: 408-924-2477
E-mail: gstudies@wahco.sjsu.edu
<http://www.sjsu.edu>

To: Amy Louise Lynn
NASA Ames Research Center, MS 262-4
Moffett Field, CA 94035-1000

From: Nabil Ibrahim,
AVP, Graduate Studies & Research

Date: November 15, 2001

The Human Subjects-Institutional Review Board has approved your request to use human subjects in the study entitled:

"Navigation Instructions and Spatial Representation."

This approval is contingent upon the subjects participating in your research project being appropriately protected from risk. This includes the protection of the anonymity of the subjects' identity when they participate in your research project, and with regard to any and all data that may be collected from the subjects. The approval includes continued monitoring of your research by the Board to assure that the subjects are being adequately and properly protected from such risks. If at any time a subject becomes injured or complains of injury, you must notify Nabil Ibrahim, Ph.D. immediately. Injury includes but is not limited to bodily harm, psychological trauma, and release of potentially damaging personal information. This approval for the human subjects portion of your project is in effect for one year, and data collection beyond November 14, 2002 requires an extension request.

Please also be advised that all subjects need to be fully informed and aware that their participation in your research project is voluntary, and that he or she may withdraw from the project at any time. Further, a subject's participation, refusal to participate, or withdrawal will not affect any services that the subject is receiving or will receive at the institution in which the research is being conducted.

If you have any questions, please contact me at (408) 924-2480.

The California State University:
Chancellor's Office
Humboldt, Chico State, Chico, CA
Dominguez Hills, Fullerton, Fullerton,
Hayward, Humboldt, Long Beach,
Los Angeles, Maritime Academy,
Ministry of Education, Pomona,
San Bernardino, San Bernardino, San Diego,
San Francisco, San Jose, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

Appendix B

Consent Form

San José State
UNIVERSITY

College of Social Sciences
Department of Psychology

One Washington Square
San José, CA 95192-0120
Voice: 408-924-5600
Fax: 408-924-5605
E-mail: psych@email.sjsu.edu

**AGREEMENT TO PARTICIPATE IN RESEARCH AT
SAN JOSE STATE UNIVERSITY**

Responsible Investigators: Kevin Jordan, Professor Psychology and
Amy L. Lynn

Navigation Instructions and Spatial Representation

- The experiment we are asking you to participate in will help us to understand if reading back navigation instruction has an adverse effect on performance. The possible benefits you might gain from by participating include learning more about the effects an interpolated task has on performance.
- You will be seated in front of a microcomputer and asked to perform a series of simple cognitive tasks (e.g., repeat instructions and perform computer task using mouse).
- There are no anticipated risks associated with performing these tasks other than those typically associated with working on a microcomputer.
- Data from this experiment will be collected through voice recorder and key presses attained from a mouse. All data you provide will be treated as confidential. Although publication of your data may occur, the data from each subject will only be associated with a subject number (rather than with a name that could identify you).
- Our primary interest is in your read back response and error rates
- You may quit the study at any time. No service of any kind, to which you are otherwise entitled, will be lost or jeopardized if you choose not to participate.
- Questions about this research project can be directed to the experimenter or to Kevin Jordan, Ph.D. (Asst. Professor, Dept. of Psychology, SJSU: 408.924.5626). Any complaints about this research may be presented to Robert Pellegrini, Ph.D. (Chair, Dept. of Psychology, SJSU: 408.924.5614). Questions or complaints about research, subjects' rights, or research-related injury may be presented to Joseph Pesek, Ph.D. (Associate Academic Vice President for Graduate Studies and Research, SJSU: 408.924.2480).

Sign below to indicate your voluntary consent to participate.

Signature (Participant)

Date

Printed Name (Participant)

Social Security #

Signature (Investigator)

Date

The California State University:
Chancellor's Office
Bakersfield, Chico, Dominguez Hills,
Fresno, Fullerton, Hayward, Humboldt,
Long Beach, Los Angeles, Maritime Academy,
Monterey Bay, Northridge, Pomona,
Sacramento, San Bernardino, San Diego,
San Francisco, San José, San Luis Obispo,
San Marcos, Sonoma, Stanislaus

Appendix C

Experimenter's Instructions

Experimenter's Instructions

OM Condition

Set up the practice session of the appropriate condition. Power up the tape-recorder and pull the tape to the magnetic portion. Dim the screen and make sure you are ready.

Politely introduce yourself and thank the person for coming. Unlock and close the door.

We will do three things today:

1. First, you will read some information about the experiment.
2. Then, you will do a practice session.
3. And then, you will do the experimental session.

I will sit right here with you during the practice to answer any questions you may have and to help you through any problems. For the experimental session, I will leave the room and shut the door, but I will be right next door in case a problem arises. I don't expect any, but just in case...

*Give the subject the information and the diagram sheets to read. While they are reading, set up the practice session if you didn't have time before. Save responses as condition (3DR) - s (subject number) - pf/a (a for accuracy file or f for full file). **Set up from the side and pull the keyboard away. ** Dim the screen.*

When they are done reading, ask if they have any questions.

Get out the model and show them it's 3 D.

Okay, so can you show me what you have to do on this model if for instance you hear an instruction such as "turn left two squares climb down two levels move forward one step"? (make sure subject shows correctly, and if not, correct it showing with your finger where the moves will be). And remember, you will never hear instructions that will take you off the grid.

Since you will always hear the directions, Left of Right, Up or Down, Forward or Back, the words Turn, Climb, Move and the words Squares, Levels, or Steps are not so important to understanding the instructions. So some of the instructions you will hear will omit the words Turn, Climb, Move and Squares, Levels, Steps, and you will simply hear instructions like "Left two, Down two, forward one."

Remember to click on **every square** you pass.

For both the practice and experimental sessions, you will hear the instructions, you repeat the instructions aloud, click the done button, follow the instructions, then click the done

button once more. There will be a two second pause before you hear the next set of instructions.

Ask subject to fit the headpiece on their head. Then adjust the mic. to the correct position. Press pause and record on the tape-recorder.

You will miss some of the instructions. We expect you to miss some; there is no way you can get them all correctly because the test is designed to be impossible. Although you will not get all of them, always try to repeat and follow as much of the instructions as you can remember.

Let them take the practice.

Check that the recorder picks up everything.

Carefully watch what they are doing - take notes if needed.

Encourage after the practice.

You did great!

You did exactly what we need you to do!

This is designed to be impossible because we are interested in the limits of people's ability to follow directions. If we did not exceed your limits we wouldn't be able to figure out what your limits are. If you did everything right, we would fail to find out as much as we could about how people follow directions.

Tell them your observations about how they did during the practice.

EX. if they said, "turn back" instead of turn left: "Saying it this way may only confuse you. The words used are designed to help you remember the instructions. The more accurately you repeat them, the better your chances are to remember them correctly."

EX. if they did Turn, Climb, Turn, This is an impossible combination. The correct order is Turn, Climb, Move.

Explain the differences between the practice and the experimental session:

1. The starting position is different, but it is the same throughout the session (*show on the screen where it will be*).
2. In the practice, it started easy and got more and more difficult. Now it will just be random: the first thing you hear might be easy or difficult, and there is no telling what the next one will be.
3. In the practice, you were given feedback telling you if you followed the instructions correctly or not. In the experimental session there is no feedback. When you are done with one instruction, you will hear the next one.
4. The experimental session is longer than the practice, but you have practiced all possible combinations of instructions. There is nothing new, there are just more of them.

Remember, there are three kinds of movements; Right or Left, Up or Down, and Forward or Back. To move Right, Left, Forward, or Back, you stay on the same grid. To move Up or Down, you must change grids. To move up or down, you must land on the same square of the other grid (*show it on the model to make it clear*).

Setup the experimental session

Save results to condition

You may start when you are ready and there will be a note on the screen to let you know when you are done. Come get me in the next room when you are finished or if you have any trouble.

****** Un Pause the recorder and make sure it records ******

Say the subject number and the condition so it's recorded on the tape.

Make sure the door is unlocked. Leave the room. Close the door.

When they are done, ask if they have any questions or comments.

Sign their green sheet for extra credit.

Thank them for donating their time to science.

Check the data files to make sure they are all there (4 files) and that they contain the right kind of data.

Put all data in the zdata folder (setup for the next subject if you have one right away).

Tape labels: Experiment/condition, S#, DATE

Backup the data files 2X.

Appendix D

Participant's Instructions

Participant's Instructions

OM Condition

"United one twenty three, turn right heading two three five, climb and maintain ten thousand, expect higher in ten, report leaving seven thousand, contact departure on one three two point seven five..."

This is the kind of instructions pilots receive from Air Traffic Controllers. Sometimes, controllers deliver longer messages, and sometimes shorter ones. Especially when controllers are under pressure, they may deliver such messages speaking very fast. Pilots don't always catch everything the controller has said and may ask for clarification. Sometimes, the pilots don't know that they didn't catch everything, and often precious time is lost in clarifying and verifying what has been said. The experiment you are participating in is exploring what happens in such situations. We are studying the limitations on comprehension set by the length of the message spoken and the speed at which it is said. To do that, you will play the role of the pilot.

When the pilot hears instructions from the Air Traffic Controller, the pilot first repeats the instructions and then follows them. You will do the same. You will hear messages instructing you to move in a simulated three dimensional space on the computer screen. You will repeat those instructions orally and then proceed to follow them. Unlike the sample Air Traffic Controller's instructions above, your instructions will not include any aviation jargon. Your instruction will be to **turn** right or left, **climb** up or down, and **move** forward or back.

Once the experiment starts, you will see on the screen four grids, one above the other. Each grid is made of sixteen squares (4X4). Your starting position is the highlighted (dark) square (see picture). To **turn** and to **move**, you always stay on the same grid. To **climb**, you go to a different grid. To follow the instructions you click the mouse in the appropriate places on the grids. The instructions have a very specific structure. Here is an example: "turn right one square, climb up two levels, move forward three steps." Because there are four grids of four by four, the numbers in the instructions are limited to one, two, and three. Also, from any position, there is a limited number of moves you could make without "falling off" the grid. The instructions are set so you won't fall off. The instructions are also very consistent in terminology. **Turn** is always associated with right or left and with a number of squares. **Climb** is always associated with up or down and with a number of levels; and **move** is always associated with forward or back and with a number of steps. You will never be instructed to "turn up" or to "move two levels." This consistency is the same as in flight operations where "turn" is always followed by right or left and a compass direction, "climb" is always followed by altitude, and "contact" is always followed by a name and a frequency. The experiment simulates the aviation scenario in one more aspect, that of the structure of the message. Your instructions will follow a fixed order. There are three kinds of movements you can make, **turn**, **climb**, and **move**, and they will always be in that order.

You will hear messages of different lengths and different phrasing. There will be messages as in the example above, and abbreviated messages with only the direction of movement and the number of steps. There will be short messages of just "turn left one square," or "left one," and there will be long messages such as "turn right two squares, climb down one level, move forward one step, turn left three squares, climb up three levels, move back one step," or "right two, down one, forward one, left three, up three, back one." You will find the long messages difficult to follow, but with practice, they will become easier. In all cases, at the end of the instructions you will hear a beep. Following that beep sound, you will repeat aloud the instructions you heard. When you are done repeating, click the DONE button. After clicking the button, follow the instructions you heard by clicking in the right places on the grid. You should click every square you "step" on. For example, you hear: "turn right one square, climb up one level" "beep"; you say aloud "turn right one square, climb up one level" and click the DONE button; then you click on the square immediately to the right of your starting position and then on the square at the same location in the grid above the one you are on; you then click the DONE button again. Following a short pause (2 seconds), you will hear the next instruction message. You should click every square you pass, so if the instructions were "turn left two squares, climb down two levels, move forward one step" you should click on the square immediately to the left of your starting position (1 on the picture) and then on the square immediately to the left of that (2 on the picture), then on the square in the same location on the grid below (3 on the picture), once more in the square in that same location on the next grid down (4 on the picture), and last on the square forward (away from you) of that location (5 on the picture). The number of clicks should equal the number in the instructions (i.e., "two squares" = two clicks, "three steps" = three clicks, etc.).

The experimental trials are presented in a random order. That is, regardless of what your last instructions were, the next message may be full or abbreviated, short or long. The starting position in all the trials is the same.

Important! You should always repeat and carry out as much of the instructions as you can remember! Don't worry when you miss a part of the instructions, we expect you to miss some.

If you have any questions, please ask the experimenter now.