The Effect of Context on Skill Acquisition and Transfer

Hui-ing Ma, Catherine A. Trombly, Carolyn Robinson-Podolski

Key Words: environment • motor control

Objective. A major concern of occupational therapy is the identification of context characteristics that optimize performance. The purpose of this study was to examine the effect of context on skill acquisition and transfer.

Method. Forty college students without disabilities (12 men, 28 women) were randomly assigned to the task of learning to use chopsticks in either a natural or a simulated context. Each participant practiced 60 trials in an acquisition phase on 1 day and was tested on a transfer task 24 hr after the acquisition phase. Their performances in the acquisition and transfer phases were measured with the variables of success rate and reaching kinematics.

Results. The natural context elicited significantly larger improvement of success rate in the acquisition phase and a significantly higher success rate in the transfer phase than the simulated context. No major difference was found in kinematic variables between the two contexts.

Conclusion. These results suggested the use of natural contexts to facilitate the outcome of motor skill learning.


Hui-ing Ma, MS, is Doctoral Student, Department of Occupational Therapy, Boston University, Boston, Massachusetts. At the time of the study, she was Master's Student, Boston University. (Mailing address: 30 Revere Beach Parkway, #302, Medford, Massachusetts 02155)

Catherine A. Trombly, ScD, OTR/L, FAOTA, is Professor, Department of Occupational Therapy, Boston University, Boston, Massachusetts.

Carolyn Robinson-Podolski, MA, OTR/L, is Clinical Assistant Professor, Department of Occupational Therapy, Boston University, Boston, Massachusetts.

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1 day after the acquisition phase, the effect of context would be identified in terms of generalizability and relatively permanent changes.

Literature Review

Ecological Approach to Perception and Action

Context affects performance. According to Gibson (1986), contexts are both physical and phenomenological in that people perceive objects in the contexts by the information these objects offer. Further, people's actions are guided by the perceived information (Reed, 1982; van Wieringen, 1996). In one of the pioneering studies that investigated this theory, five healthy participants were asked to grasp either a lightbulb or a tennis ball of similar diameter, and the three-dimensional movement trajectories of their reaching phases were recorded (Marteniuk, MacKenzie, Jeannerod, Athenes, & Dugas, 1987). It was found that the movement time and deceleration phase were significantly longer for grasping a lightbulb than were those for grasping a tennis ball. The findings suggested that the participants planned a more careful movement in grasping the lightbulb because they perceived it as fragile.

Enriched versus impoverished context. Given the evidence that contexts could affect movement organization, occupational therapy practitioners could further inquire how to manipulate contexts to facilitate movement. From the ecological perspective, a context with rich sources of information could elicit better performance relative to an impoverished context (van Wieringen, 1996). Further, the richness of contexts could be described in terms of visual and auditory feedback. Feedback provides information regarding a person's relation to the context. Thus, the attainment of a task requirement is readily perceptible by the performer, whereas, in the impoverished context without this feedback, the information about movement relative to the context is limited, thus restricting the improvement of performance (van der Weel et al., 1991). Several studies have varied the context by offering different levels of visual and auditory feedback, and their results support the superiority of enriched context to impoverished context (Mathiowetz & Wade, 1995; van der Weel et al., 1991; Yuen et al., 1994). With regard to their dependent variables, all of these studies examined the immediate motor performance during treatment, except the study by Yuen et al. (1994), which looked at the performance over successive periods. In this study, the authors required college-age participants without disabilities to learn to operate an above-elbow training prosthesis under two conditions: (a) joining dots with a flashlight attached to the hook of the prosthesis and (b) practicing flexing and extending the prosthesis at the elbow joint but without the light or dots. Thirty seconds after the practice sessions, participants learning with the special visual input performed consider-ably better on a tracing task than did the participants lacking that visual input and goal.

Natural versus simulated context. It has been argued that practice of real tasks that are important to patients enhances functional performance more than does practice of the simulated tasks often used in clinical practice (Mathiowetz & Haugen, 1994). Gibson (1986) stated that natural contexts provide rich sources of structured, informative energy for perception, allowing perception to map directly onto action; thus, there is minimal need for cognitive mediation. Therefore, a natural context would elicit more efficient and effective performance than would a simulated context. Several studies have investigated the relative effect of natural and simulated contexts on the performance of functional tasks (Mathiowetz & Wade, 1995; van Vliet et al., 1995; Wu, 1995; Wu et al., 1994). Among these studies, Mathiowetz and Wade (1995), Wu (1995), and Wu et al. (1994) provided evidence that the natural context elicited much faster and much more direct reaching performance than did the simulated context.

van Vliet et al. (1995) used a similar task as in the Mathiowetz and Wade (1995) study; however, van Vliet et al. found no significant differences among conditions. A closer examination of these two studies suggests that this discrepancy may have resulted from what the participants did with the objects (cup, water), which were different in these two studies. Mathiowetz and Wade asked participants to drink (drinking task), whereas van Vliet et al. had participants move the cup (moving task). From an ecological viewpoint, van Wieringen (1996) emphasized the strong interrelations between movement and perception; namely, perception provides the information that guides movement; movement, in turn, is an essential aspect of the act of perception. Thus, given the similar objects (cup, water) in these two studies, the drinking movement made the cup of water more ecologically meaningful than did the moving movement (Reed, 1982). Therefore, manipulation of the cup and water in the drinking task made more difference between natural and simulated contexts than in the moving task. In light of this, it seems important to consider action and perception as a unit and from a functional perspective (Pick & Rosengren, 1991).

Motor Learning

Occupational therapy practitioners assist patients in learning new skills and emphasize the relevance of the skills to achieving a more independent existence (Gliner, 1985). The modern perspective of motor learning claims that learning represents relatively permanent changes in the capacities of responding and, therefore, has to be evaluated on retention or transfer tests. In a retention test, participants perform the same skill that they have been practicing some time after the acquisition phase has been completed, whereas in a transfer test, participants use the skill they
have been practicing but in a new situation. The transfer test, which is also the measure of generalizability, is regarded as especially important because the skills being learned are usually expected to be performed under various real-world conditions (Magil, 1989). A primary defining characteristic of retention and transfer tests is that they are given with sufficient layoff from the tasks so that temporary effects have been removed (Mathiowetz & Haugen, 1994; Schmidt, 1991). Yuen et al. (1994) explored the effect of enriched context on motor skill training. However, it is questionable that a 30-sec interval between the practice and transfer is enough time to allow the temporary effects to dissipate. There is a need to study the effect of context on skill learning with a longer interval between the training and transfer phase.

From the ecological perspective, learning a skill is learning how to use the affordances of the environment (Reed, 1982). Following similar logic, an enriched, meaningful context is also beneficial for learning (Gliner, 1985; Newell, 1989, 1996; Schmidt, 1991). Therefore, using real objects in a natural context is recommended for development of new skills because it provides a much richer source of informational support than the simulated context with contrived objects.

Movement Kinematics

Several studies reviewed in this article employed kinematic variables as criterion measures. The use of kinematics allows quantitative measurement of the three-dimensional trajectory of the moving limb and the detection of underlying movement strategies that are not directly observable (Schmidt, 1988). Kinematics include movement time, total displacement, and amplitude of peak velocity. Movement time is the time for executing the reaching movement. Total displacement refers to the path of a hand in three-dimensional space. When the arm starts to reach for a target, it generally accelerates toward the target and then decelerates to change the direction or correct the trajectory (Georgopoulos, 1986). Peak velocity in the velocity profile corresponds to the changeover from the acceleration to deceleration phase. It has been demonstrated that with learning, movement becomes faster (i.e., decreased movement time) and straighter (i.e., decreased total displacement) (Corcos, Jaric, Agarwal, & Gottlieb, 1993). In addition, through learning, movement becomes more automatic, and this is reflected in decreased movement units, increased peak velocity, and increased percentage of reach where peak velocity occurs (Brooks & Watts, 1988).

Hypotheses

On the basis of the ecological approach (Gibson, 1986) and empirical findings of research on context, it was hypothesized that in the acquisition phase, the natural context would elicit greater improvement in performance than the simulated context; that is, more decreased movement time, decreased total displacement, and increased peak velocity. In addition, it was predicted that learning to use chopsticks in the natural context would result in better performance on the transfer task than would learning in the simulated context, which would be reflected in higher success rate, shorter movement time, shorter total displacement, and higher peak velocity.

Method

Design

A simple randomized design with two independent groups was used. Each participant was assigned randomly to one of the two groups—the natural context or the simulated context.

Participants

Forty right-handed college students without disabilities (12 men, 28 women) at Boston University volunteered for the study and were paid a small stipend. The participants’ ages ranged from 19 to 31 years (M = 23.75, SD = 3.46). None of them were occupational therapy students. The participants reported either no previous experience in using chopsticks, or, if they had tried to use them, they had never successfully picked up food three times consecutively. None of the participants were restricted from eating cheese or pasta products because this study required them to eat these foods.

Materials

In the acquisition phase, a pair of metal chopsticks .5 cm in diameter and 24.0 cm in length was used. The target objects in this phase were small chunks of cheese (natural context) and small chunks of eraser (simulated context), both measuring .8 cm × .8 cm × .6 cm. The objects were put on a dish measuring 10.0 cm × 7.2 cm × 3.3 cm. In the transfer phase, the participants used wooden chopsticks .5 cm in diameter and 23.2 cm in length. The target object in this phase for both groups was cooked shell-shaped pasta that was put on a round plate measuring 13.5 cm in diameter and 4.7 cm in height.

Instruments

A subtest of the Minnesota Rate of Manipulation Test (MRMT), the One-Hand Turning and Placing Test, was used to measure dexterity, which was considered a possible moderating factor. The score was the total number of seconds required to complete two test trials. The reliability of this subtest has been established for two trials (r = .95) on 212 young, male machine operators (Jurgensen, 1943).

The participants’ performance was video recorded and evaluated by counting the number of successful trials out of
20 when using chopsticks to pick up objects. The successful trials were counted by the experimenter and a research assistant, who was blinded to this study. Interrater reliability was .94, using intraclass correlation coefficient (ICC).

The three-camera OPTOTRAK™/3020 system was used for recording three-dimensional reaching performance. One infrared light-emitting diode (IRED) was attached on the ulnar styloid of the participant's right hand. The position of the IRED over time was sampled by OPTOTRAK at a frequency of 100 Hz. Reliability of the OPTOTRAK was greater than .99, using ICC (Trombley, Wu, & Cope, 1994).

A microswitch connected with the OPTOTRAK data acquisition unit (ODAU™) was used to indicate when the participant lifted his or her hand off the starting position, the start of movement. On the basis of pilot data, the end of movement was defined as the first point in time when the plateau in the Y-displacement profile lasted more than .1 sec. After being collected, the data were converted from two-dimensional to three-dimensional coordinates by a direct linear transformation algorithm and then stored for off-line analysis.

Procedure

Before the experiment, each participant was assessed with the MRMT One-Hand Turning and Placing Test. Two trials were performed and scored by the experimenter. After this assessment, each participant was given written instructions and diagrams on the rules for using chopsticks. The instructions were as follows:

The purpose of this study is to see how you learn to use chopsticks to pick up small chunks of cheese/eraser. First, tuck one chopstick under your right thumb and hold it firmly. Second, add the second chopstick and hold it as you would hold a pen. Third, move the second chopstick up and down while holding the first chopstick in its original position.

While reading through the instructions, the participants had chopsticks in their hands and were asked to perform the three steps in the instructions. After being able to do the third step, they were randomly assigned to the natural or simulated context group. Each group had 20 participants.

Acquisition phase. Each participant sat in front of a table in the same testing room. The target objects were placed 36 cm away from the body in line with the participant's midsagittal plane. In the beginning of each trial, the participant held the metal chopsticks in the operational position while touching on a hand pad located directly in front of the participant's right shoulder. After the experimenter said go, the participant reached out to pick up one chunk of target objects. For the natural context group, the participant was asked to pick up cheese, bring it back to the mouth, and eat it. For the simulated context group, the participant was asked to pick up eraser and bring it back to the mouth. The acquisition phase consisted of six blocks, each with 10 trials. In the beginning of each block, the experimenter checked that there were 10 chunks of cheese or eraser in the dish. Of the six blocks, only Blocks 1 and 6 were recorded. After finishing this phase, the participant was asked not to practice using chopsticks during the 1-day interval between the acquisition and transfer phases.

Transfer phase. Twenty-four hours after the acquisition phase, at the same place, participants were asked to use wooden chopsticks to pick up cooked shell-shaped pasta from a round plate, bring it back to the mouth, and eat it. The participant's initial hand position and the position of the target food were the same as in the acquisition phase. Participants were required to perform one block (i.e., Block 7) of 10 trials in this phase, and all trials were recorded.

Data Reduction and Analysis

The raw video-recorded data were analyzed for successful trials. A successful trial was defined as picking up one object on the first attempt by bringing two chopsticks together and bringing the object back to the mouth. The number of each participant's successful trials in Blocks 1, 6, and 7 was averaged over 10 to obtain the success rate of each block.

The converted OPTOTRAK data were filtered at a low-pass cutoff frequency of 5 Hz using a second-order Butterworth filter with forward and backward passes by the Northern Digital Data Analysis Program (DAP; Northern Digital Inc., 1992). Scores for the kinematic variables were obtained from a custom-written computer program and then averaged over 10 trials for Blocks 1, 6, and 7.

Acquisition phase. The dependent variables in this phase were the change of performance between Blocks 1 and 6. The correlations between the MRMT score and the dependent variables were then computed. On the basis of the results (change of success rate, \( r = .46, p = .15 \); change of movement time, \( r = .27, p = .09 \); change of total displacement, \( r = .23, p = .15 \)), analysis of covariance (ANCOVA) was used to examine the change of success rate, movement time and total displacement as a function of contexts while controlling for hand dexterity. The change of peak velocity in both groups was compared by an independent t test because it appeared to be unrelated to hand dexterity (\( r = -.05, p = .76 \)).

Transfer phase. The dependent variables in this phase were the scores in Block 7. Low correlations between the MRMT score and the dependent variables were found (for success rate, \( r = .07, p = .69 \); for movement time, \( r = -.01, p = .91 \)).
p = .96; for total displacement, r = -.13, p = .44; and for peak velocity, r = -.06, p = .72). Therefore, independent t tests were conducted to compare the results of the two groups.

**Results**

**Acquisition Phase**

Table 1 displays the means and standard deviations of the dependent variables in this phase. For change of success rate, results of the ANCOVA indicated significant differences between the two groups, \( F(1, 37) = 5.05, p = .03 \), effect size\(^4\) \( r = .35 \). Further, examination of the adjusted means indicated that success rate for the natural context group (\( M = .22 \)) was significantly higher than that for the simulated context group (\( M = .08 \)). However, for the reaching kinematics, the group main effect was found to be nonsignificant for change of movement time, \( F(1, 37) = .02, p = .88, r = -.02 \), and for change of total displacement, \( F(1, 37) = .18, p = .67, r = -.07 \). For change of peak velocity, the \( t \) test yielded a value of \( t(38) = -1.29, p \) (one-tailed) = .10, \( r = -.20 \). Although negative, the effects were quite small, suggesting that the participants in the two groups performed almost the same in terms of reaching kinematics.

**Transfer Phase**

Because of technical problems with the videocamera, one participant’s success rate was missing. The independent \( t \) test on the success rate revealed a significant difference in favor of the natural context group, \( r = .30 \) (see Table 2). With regard to the kinematics, the results were not significant for movement time, \( r = .07 \), total displacement, \( r = -.11 \), or peak velocity, \( r = .04 \). The small effects of these variables indicated that the participants’ reaching kinematics in the two groups were almost the same.

**Discussion**

This study examined the effect of context by using dependent variables of success rate and movement kinematics. The a priori hypotheses were supported by the success rate results, but not by the kinematics (i.e., movement time, total displacement, peak velocity). That is, in the acquisition phase, the natural context group had a significantly larger improvement in success rate than did the simulated context group. Moreover, in the transfer task where the types of chopsticks and target objects were changed, a considerable transfer of learning took place in the natural context, for it had a higher success rate than the simulated context group in the transfer task.

The results of the success rate agree with those of the previously reviewed studies, showing that an enriched, natural context elicited better performances than did an impoverished, simulated context. These findings lend support to the ecological theory (Gibson, 1986). According to Gibson’s theory, the chopsticks used in this study were perceived as the “tool for eating,” and the cheese in the natural context was perceived as “edible.” The meaning of the eraser in the simulated context, however, was ambiguous. Therefore, the action of using chopsticks to pick up and eat cheese was probably generated directly with less cognitive mediation, whereas the use of chopsticks to pick up the eraser and bring it to the mouth was a contrived action with a conscious goal. Moreover, for the natural context group, the movement of getting the cheese and eating it in turn became an essential aspect of the act of perception. The biological information afforded by the cheese, therefore, facilitated a direct, strong, and successful relationship between participants and the natural context. By contrast, the simulated context group lacked the subsequent informational support for getting the eraser, so the participants built a less successful relation with the context, as reflected in both the acquisition and transfer phases.

In contrast to the success rate, the results of kinematic variables were different from the hypotheses. A closer examination could lead to a more complete insight into the effect of context. We offer several possible explanations as well as future research strategies to clarify these possibilities. First, manipulations of context in this study might not have been strong enough. In many of the reviewed studies, context was varied by the presence or absence of target objects (e.g., Sietsema et al., 1993; Wu et al., 1994; Yuen et al., 1994). Under these conditions, the goal was varied as either concrete or abstract, and the level of difficulty varied similarly. But this study used target objects (i.e., cheese chunks, eraser chunks) of similar size, weight, and surface properties in both groups. Consequently, the goal of learning to use chopsticks was concrete, and the level of difficulty was similar for all the participants. It is possible that this way of operationalization led to a smaller effect relative to the reviewed research. Future research may systematically evaluate the differences of performance under various amounts and types of object affordances.

Second, in terms of practice schedules, the natural context, as operationalized in this study, might not have reflected accurately on real-life situations. To apply experimental controls, this study adopted a blocked, massed practice schedule. This type of practice usually occurs in clinical contexts, whereas practice in real life is more likely to be random and distributed. Therefore, the practice schedule made the simulated context in this study close to clinical practice but made the natural context different from real-

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\( ^4 \)The effect size \( r \) represents the degree to which the phenomenon under study is manifested. According to Cohen (1988), a large effect is considered by a \( r \) of at least .50, a moderate effect by .30, and a small effect by .10. In addition, the effect size for a specific hypothesis was positive if the result supported the hypothesis; otherwise, the effect size was given a negative sign.
life situations. On the basis of this argument, the impact of natural context in this study should be interpreted with caution. Future research could manipulate contexts and practice schedules simultaneously to explore their individual main effects and their interaction effect.

Third, the effect of natural versus simulated context may be confounded with the phenomenon of speed-accuracy trade-off. Just as persons do not necessarily move quickly when eating meals, participants in the natural context group may have perceived the goal to be "getting" the cheese rather than "getting it fast"; therefore, they made a larger improvement in their success rate but not in their movement kinematics in the acquisition phase. Additionally, although participants in the natural context group needed a little time to eat the cheese before starting the next trial, the simulated context group could practice the trials immediately one after another. Such a quick rhythm in the simulated context may implicitly have made the participants perceive the task as an exercise and want to do it faster and faster. Therefore, they ignored the criterion of accuracy and made a smaller improvement in their success rate. The possible influence of the speed-accuracy trade-off phenomenon on daily tasks warrants further scrutiny. In addition, criteria of a "good" movement organization should be explored, especially when there is a need to balance speed with accuracy. The criteria used in this study (i.e., shorter movement time, shorter total displacement, higher amplitude of peak velocity) seemed to place more emphasis on speed. However, a quick movement that does not accomplish the goal is hardly considered better than a slow movement that achieves the goal. Future research may investigate patterns of movement performance in real life; for example, to what extent do persons move efficiently in different tasks in real-life contexts?

Fourth, participant characteristics might be another possible reason for the results that diverge from our hypotheses. Many of the reviewed studies included participants with neurological impairments, such as stroke, cerebral palsy, and multiple sclerosis. The young, healthy adults used in this study may have been less susceptible to the subtle influence of context than the participants with neurological impairments in other studies. It is possible that the healthy adults did well in both natural and simulated contexts because their intact sensory systems could compensate for the impoverished informational support (van der Weel et al., 1991). In addition, a meta-analytic study about the effect of context demonstrated that a significantly larger mean effect was found in the populations with neurological impairments than in the populations without neurological impairments (Lin, Wu, Tickle-Degnen, & Coster, 1997). To confirm the findings of the present study and search for effective treatments for specific populations, future research should encompass different clinical populations.

Clinical Implications

This study provides information on the effect of context, thus connecting the contemporary ecological approach of psychology with occupational therapy theory and practice. Although the overwhelming majority of the reviewed studies examined immediate responses, this study used a transfer test 1 day after the acquisition phase and demonstrated a moderately permanent and generalizable effect of context. Moreover, this study included both success rate and reaching kinematics to evaluate motor skill learning. A

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<td>Means and Standard Deviations of the Dependent Variables in the Acquisition Phase</td>
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<td>Change of movement time (.01 sec)</td>
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<td>Change of total displacement (mm)</td>
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<td>Change of peak velocity (mm/sec)</td>
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*Note. n = 20 for each group. Change of dependent variables = scores in Block 6 - scores in Block 1.*

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<td>Independent t Test for the Dependent Variables Between the Two Groups in the Transfer Phase</td>
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<td><strong>Variable</strong></td>
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*Data of one participant's success rate were missing.

Note. n = 20 for each group.

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combination of these two kinds of dependent measures provides more comprehensive information about the effect of context than does using either one individually.

This study suggests that therapists should be aware of the speed-accuracy trade-off phenomenon in task performance. The confounding effect of this phenomenon in the present study is likely to be more obvious in clinical populations because these persons have more difficulties in moving both quickly and accurately. Therefore, clinicians may arrange the context according to which goal (i.e., speed or accuracy) is more important at a patient's current stage. That is, when the goal of accuracy is crucial, real objects may be used as an effective way to facilitate the outcome of motor skill learning (e.g., success rate). If the goal of speed is to be emphasized, a simulated context with concrete goals could be used because a simulated context may elicit movement kinematics similar to those of a natural context. In addition, therapists may optimize patients' performance by using instructions such as "as fast as you can" or "as accurately as possible" to balance speed with accuracy. Future research is needed to confirm the validity of these findings and clinical implications.

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