Distinguishing of Error Awareness from Error Correction

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ABSTRACT

The current study was designed to test whether error awareness can be dissociated from error correction in typing behavior. According to the "Hierarchical Control Theory", skilled typing is controlled by two hierarchically organized loops (Logan & Crump, 2011): The outer-loop (higher level), which generates words and receives feedback from the screen, commands the inner-loop (lower level), which produces finger movements i.e., executing keystrokes. The main aims of the current study were to demonstrate how error correction can be implemented in these two hierarchically organized loops and, in particular to investigate the error correction at the lower level. Data from twenty Turkish speaking participants were analysed in the current study. Typing performance of participants were measured under two visual feedback conditions (responses either were or were not appeared on the screen). The findings showed that participants can detect and correct their typing errors when their responses did not appear on the screen. In addition, there was no significant difference between the rates of error detection and error correction under no visual feedback condition. Theoretical and applied implications of these findings were discussed.

Keywords: Typing process, Error Correction, Error Detection, Hierarchical Control Theory.

ÖZ

Bu çalışma klavyede yazım davranışını kullanarak hata farkındalığının hata düzeltmeden ayrılabilir olup olmadığını sınamak için tasarlanmıştır. Hiyerarşik Kontrol Teorisi'ne göre, klavyede yazım, hiyerarşik olarak organize edilmiş iki döngü tarafından kontrol edilir (Logan ve Crump, 2011): Kelimeleri üreten ve ekrandan geri bildirim alan dış döngü (üst düzey), parmak hareketlerini üreten, yani tuş vuruşlarını gerçekleştiren iç döngüye (alt düzey) komut verir. Bu koşullar altında, mevcut araştırmanın asıl amaçları, hata düzeltmenin Hiyerarşik Kontrol Teorisi'ne nasıl uygulanabileceğini incelemek (Logan ve Crump, 2011) ve özellikle alt düzeyde hata düzeltmeyi araştırmaktır. Araştırma, yirmi Türkçe konuşan katılımcı ile gerçekleştirilmiştir. Katılımcıların yazma performansı, yazılanların ekranda görünüp görünmemesi ile iki görsel geri bildirim koşulu altında ölçülmüştür. Araştırma bulguları, katılımcıların yazdıkları ekranda gözükmediğinde de hatalarını algılayabildiğini ve düzeltebildiğini göstermiştir. Ek olarak, görsel geri bildirim olmadığında hata tespiti ve hata düzeltmesi arasında belirgin bir fark bulunmamıştır. Bu bulguların teorik ve uygulamalı sonuçları tartışılmıştır.

Anahtar Kelimeler: Klavye ile Yazım, Hata düzeltmesi, Hata Farkındalığı, Hiyerarşik Kontrol Teorisi.

To my mother

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF SYMBOLS AND ABREVIATIONS

CRT	Choice Reaction Time
e.g.,	Example gratia
et al.,	And others
HCT	Hierarchical Control Theory
IKI	Inter-keystroke Interval
i.e.,	That is
M	Mean Score
ms	Milliseconds
n	Sample Size
p	Probability
PES	Post-Error Slowing
PpES	Post Partial Error Slowing
SD	Standard Deviation
SPSS	Statistical Package for Social Science
VF	Visual Feedback
W	Shapiro-Wilk Test for Normality
WPM	Word per Minute
Z	Standard Scores

Chapter 1

INTRODUCTION

1.1 Why Errors (and Detecting Them) are Important

Errors are generally described as unwanted and unexpected consequences of performances. Ullsperger and Von Cramon (2004) defined errors as results that deviate from those originally intended ones, implying that they at least hinder the achievement of the objectives, and that sometimes individuals may be hurt by these errors. When one thinks about how many ways a behavior can go wrong, it seems that errors can take an infinite number of kinds (Reason, 1990, 2000; Woltz et al., 2000).

In general, these errors can result in negative consequences such as minor incidents or catastrophic events (see e.g., Logan & Crump, 2010), but also in positive consequences such as long-term benefits i.e., behavioural adaptation, skill acquisition, and learning (Ullsperger & Von Cramon, 2004). Moreover, these errors trigger sudden remedial processes such that the intention could still be reached (i.e., error correction, Ullsperger et al., 2014). Errors are also valuable instruments to study cognitive functions such as cognitive control and performance monitoring mechanisms in experimental conditions and to analyse adaptive actions.

Errors often leave their mark on subsequent behavior. One of the differences between error performance and error free performance is post-error slowing (PES): individuals' response times usually become slower after they make an error (Rabbitt, 1966; Rabbitt

& Rodgers, 1977). A second difference is that errors are found to be followed by a lower error rate in the following trials (Laming, 1979). These observations suggest the existence of an error detection mechanism which can influence post-error behavior. Several theorists have described the error detection mechanisms to be reliant on detection of a discrepancy between intended and actual outcomes (Ito et al., 2003; Scheffers & Coles, 2000). Alexander and Brown (2010) have reviewed several computational models of impacts of errors, error detection mechanisms, conflict monitoring, error likelihood prediction. Most of the studies which were using discrete trial tasks (e.g., choice response time (CRT) tasks) have shown that individuals detect their errors after they have occurred (for a review of reactive vs. proactive error detection, see Alexander & Brown, 2010). When an error has been detected, the executive system can react to enhance performance both in short term (by applying remedial steps in accordance with the error, such as the slowing down response speed in the next trial Rabbit (1978), Shaffer, (1975); and in the long term (by modifying the response processing mechanism to avoid repeating the errors, Ohlsson, 1996; Schall et al., 2002). However, these theories have been formulated using behavioural tasks with only two alternative response options (Ohlsson, 1996; see Alexander & Brown, 2010, for a review of these models).

Different experimental paradigms have been used to study errors and error monitoring. These include antisaccade tasks (Niewenhuis et al., 2001), different forms of flanker tasks (Ullsperger & von Cramon, 2006; van Veen & Carter, 2002) and go/no-go tasks (O’Connell et al., 2007; Scheffers et al., 1996). Many such performance monitoring studies use error-related parameters such as PES and post-error accuracy to study error monitoring processes. While such discrete trial tasks have been invaluable tools for investigating and making important discoveries about cognitive processes such as attention, learning, memory and cognitive control, they can be difficult to implement under more natural circumstances. Thus, it is important to test the ideas generated by findings from these studies on everyday activities.

It is often not easy to bring day-to-day activities to the research laboratory. Some of these difficulties involve the absence of control over the behaviour by the researcher(s). A second and closely related issue is regarding objectively labelling / categorizing actions as correct vs. error in these tasks (Kalfaoğlu & Stafford, 2014). For example, there are multiple ways to perform actions in real-life situations, e.g., preparing tea, driving a car etc. Let's take making tea as an example. The goal of preparing a cup of tea involves many sub-goals: pour some water in the kettle, turn the kettle on, get a cup from the cupboard, get a tea bag, put it in the mug, etc. An error can take place during the execution of any subgoal. In addition, the temporal ordering of these subgoals is also essential (e.g., turning the kettle on, getting the mug, putting the tea bag in the mug and then filling the kettle with water pouring the water into the kettle would be an obvious error).

Executing all the sub goals and then turning the kettle on at the last step (i.e., after the water has been poured into a mug with the tea bag) is a clear example of an error. But what about pouring the boiling water into the mug before getting a tea bag, or vice versa? Should one prepare the mug and the tea bag before boiling the water, or after? Classifying actions as correct vs. incorrect in an objective manner is difficult unless some form of control is introduced (e.g., by introducing rules "always boil the water before preparing the mug", "always pour in the boiling water before putting the tea bag in the mug") by the researchers. However, as more of such rules are introduced, the task risks becoming less and less natural (i.e., less and less ecologically valid).

If one compares these day-to-day activities to typing, one can argue that natural, every-day typing can only be accomplished in one way: Typing the correct letters in the correct order. This is one advantage of typing over many naturalistic tasks. Errors do happen in natural tasks like making tea and typing, but for the reasons outlined above, it is difficult to objectively define and categorize errors in these daily tasks like making tea, compared to typing. Using typing also has some advantages over using lab-based discrete trials tasks such as Stroop, Flankers or Go/No-go tasks as well. In the following paragraph, we discuss why typing is a good method for studying errors compared to discrete trial tasks.

1.2 Why Typing is a Good Method to Study Errors

Typing has strong ecological validity. Typing behavior can be described as a daily action and individuals have a chance to improve their performance with substantial amounts of practice. According to data gathered from 1984 to 2015, the use of the Internet and computers has increased significantly over the years (Ryan & Lewis, 2017). This rise has indirectly increased the use of the keyboard. Besides this significant increase in the use of the keyboard, Salthouse (1986) emphasized the transcription typing advantages compared to other forms of activities as a tool to study human cognition.

First, the number of typists is large and this makes it easy to find moderate-sized samples of typists at a variety of expertise levels. Second, while typing behavior is continuous, separate keystrokes can be easily identified and classified as errors or not (see the previous paragraph). Lastly, although typing behaviour might appear to be a simple process, it consists of detailed and complex interactions between cognitive, motor and sensory processes (Salthouse, 1986), allowing the study of motor as well as cognitive processes.

1.3 Why Typing is a Good Method to Study Error Detection

One critical element of error detection studies is objectively and accurately recording participants' error awareness responses. For example, in Flankers tasks participants are asked to respond to the identity of the certain stimuli and to ignore the distractors often presented on sides (flankers). For instance, in Maier et al., (2008) were instructed to press the appropriate buttons ("W", "S", "L" and "P") with a certain way (the fingers were indicated). And if participants detected an erroneous response, they were instructed to report an error signalling response by pressing the two buttons ("Alt" and "Alt-Gr") with their thumbs. This would be an unnatural way to signal error awareness. Because, across trials one needs to remember which way to respond to certain stimuli and this would constitute additional load on cognitive resources of the participants (e.g., on the working memory system).

In relation, the assessment of error awareness in discrete trial tasks is often evaluated with a binary response set. This means that the participant can only signal that they made a mistake, or not. Often, there is no option to indicate uncertainty, which may be the case in many trials. The main issue comes from the assessment of the conscious error awareness of participants with this type of binary system; individuals may feel that they are obliged to label their performance in accordance with this binary response set (either correct or incorrect). Even if they are not sure whether they have made an error, they may report the error, potentially decreasing the validity of the results gathered using this method.

One advantage of using typing behavior to study error awareness compared to discrete trial tasks is that it is easy to track participants’ error awareness or error detection using an overt and highly practiced way of signalling error detection, namely pressing the backspace. Because it is highly practiced, it becomes a natural part of the typing skill set. Because of the high level of practice, the cognitive load associated with accurately labelling/correcting an error will also be smaller. In summary, more cognitive effort is needed in cases where individuals are required to signal errors in novel discrete trial tasks compared to typing. The level of practise in typing makes it easier to signal errors.

1.4 Hierarchical Control Theory of Typing

The Hierarchical Control Theory of Typing (HCT) has been developed to demonstrate how skilled typing is controlled (Logan & Crump, 2011). Skilled typing behaviour requires both cognitive (i.e., generating ideas, reading, creating word sequences, monitoring previously typed words) and motor processes (i.e., coordinating and executing keystrokes with fingers). Logan and Crump (2011) developed this model to explain how these processes interact to accomplish typing behaviour.

Documents to be typed are made up of several paragraphs, paragraphs are comprised of sentences, sentences are comprised of words, and words are comprised of letters. In this sense, material to be typed is hierarchical. Likewise, a hierarchical organization also exists in the typists' mental representations involved in controlling typing actions (Logan & Crump, 2011). There is a mechanism that handles larger units and such higher-level processes as generating thoughts and ideas that need to be typed, reading, transforming these into sentences and eventually to words. These processes are controlled by a higher level, the so-called “outer-loop”. Another mechanism that is lower in the hierarchy handles smaller unit(s) and lower-level objectives (e.g., keystroke execution). These processes are controlled by the so-called “inner-loop” (Logan & Crump, 2011).

There are a number of propositions of the HCT (Logan & Crump, 2011) that are important for the current study. First, Logan (2003) stated that the outer loop transfers the information to the inner-loop at a word-level. In other words, the linguistic unit that gets sent down from the outer loop to the inner loop is the word (rather than the letter or a sentence, Logan & Crump, 2011). Second, the theory claims that the outer-loop determines which word will be typed, but it doesn’t have any information regarding the processes taking place in the inner loop such as the information regarding which letters of that word are being typed by which finger at any given moment (Logan & Crump, 2009). In other words, the inner loop is “informationally encapsulated”.

Third, and most importantly, this theory makes claims regarding how typing performance is monitored for errors. It suggests that outer-loop and inner-loop rely on different sources of information to evaluate the accuracy of the executed behavior (Logan & Crump, 2010). The outer loop checks the accuracy of the typed entries using the computer screen. If there is a discrepancy between executed behaviour as shown on the screen and the intended behaviour, the outer-loop determines that an error has been made. Researchers often evaluate error detection at the outer loop level by asking explicit questions about the accuracy of what has been typed to the participants (Logan & Crump, 2011; Snyder et al., 2015).

On the other hand, the inner loop checks the accuracy of typed entries using *sensory feedback* from fingers. If there is a discrepancy between executed behaviour and intended behaviour, the inner loop determines that an error has been made (Crump & Logan, 2013; Gordon & Soechting, 1995; Logan & Crump, 2011; Yamaguchi & Logan, 2014). Researchers evaluate error detection at the inner loop level by calculating PES (Rabbitt, 1966, 1978). PES is characterized by slower response times after the error compared to after the correct responses (Rabbit, 1966). In typing, PES can be observed at the letter level i.e., after the erroneous keystroke, subsequent key-presses are significantly slower (Crump & Logan, 2013; Kalfaoglu & Stafford, 2014). In general, PES was observed in many different tasks and there are many propositions on the underlying processes that drive effect (for a review, see Danielmeier & Ullsperger, 2011). Below we describe several studies that focus on PES to provide a better understanding of it.

In one study, Crump and Logan (2013) investigated the role of PES in typing with manipulating the error correction processing i.e., backspace button. They investigated whether typing errors were accompanied by more careful and precise typing that could be described as a prevention strategy or test the novel hypothesis that the PES may arise from inhibiting the automatic propensity to make error corrections when backspacing is not allowed (or the backspace key is disabled). They showed that the PES was only observed when participants were not allowed to make error correction i.e., when the backspace button was disabled. They concluded that their findings supported the proposition the PES indicated inhibition of the prepotent propensity to make error corrections following erroneous keystrokes.

Kalfaoğlu and Stafford (2014) conducted another study examining the pre-and post-error performance in terms of speed and accuracy, and their findings were contrary to the findings of earlier findings (see Crump & Logan, 2013). Kalfaoğlu and Stafford (2014) stated that error and post-error key pressing were slowed down regardless of the error correction process i.e., the error and post-error key pressing were slower compared to correct key-pressing, whether the error was corrected or not. The discrepancy between the results of these two studies might be related to the differences in their methods. First, there are some differences between these two studies i.e., one difference was related to the use of a different baseline for measuring PES and the latter study was focused on pre-error rather than post-error performance. Kalfaoğlu and Stafford (2014) suggest that their findings are more in line with a view of PES as an index re-orientation (or shift from habitual to a more controlled execution of actions) rather than an index of inhibition.

Lastly, Logan and Crump (2010) argued that error detection at the inner loop (i.e., PES) and that at the outer loop can dissociate. They conducted a study in which typists typed single words and rated their own accuracy at the end of each trial. The researchers generated inconsistencies between what typists typed and what was shown on the screen. In some of the trials, they corrected typists' mistakes, so the screen suited typists' intentions, but not their motor actions (“Corrected Error” condition). In some of the other trials, Logan and Crump (2010) inserted errors that were not made by the participants, so their motor behavior matched their intentions, but the screen showed an error the typists didn't make (“Inserted Error” condition).

When asked explicitly (i.e., at the outer loop level) if they made any mistakes in the current trial, participants displayed “cognitive illusions of authorship” for corrected errors: the participants were more likely to report the “corrected errors” as “correct” responses. The authors reported that no such illusion was found in the case of inserted errors, i.e., the participants reported inserted errors as they were. Crucially however, they observed that the cognitive illusion of authorship did not affect inner loop processing: While the participants displayed PES (a sign of error detection at the inner loop) for corrected errors and actual errors, there was no PES following inserted errors. It is therefore arguable that these nested loops are at least partially dissociable in terms of detecting errors (Logan & Crump, 2011). One of the primary aims of the current thesis is to see if the dissociation in error detection can be shown for error correction too.

1.5 Error Detection is Important, but Error Correction is More Important in Many Ways

Error detection plays a central role in the performance of individuals; they realize whether or not their performance involves an error. And error correction is at least as important as error detection. Only the error correction process can resolve the error, and improve performance in the short run. *The current study intends to determine whether error correction in typing (i.e., backspacing) will be more related to inner loop processes or to outer loop processes*.

Error correction seems to be an automatic process that persons undergo after initiating or making an error even in discrete trial tasks. For example, Rabbit (1966) found that participants displayed simultaneous error corrective responses even though they were directed to inhibit such remedial responses (Maylor & Rabbit, 1987; Rabbit & Rodgers, 1977).

In natural, continuous typing, a detected error often results in pressing down of the backspace, and subsequent key-presses to complete the word that is being typed. What happens after an error is detected is not strictly specified by the HCT (Logan & Crump, 2011). To our knowledge, previously only a small number of studies used HCT as a theoretical framework to investigate error correction in copy-typing (Crump & Logan, 2013; Kalfaoğlu & Stafford, 2014). In our understanding of this theory, the inner loop is a “slave” system which executes the commands it receives from the outer loop. In other words, the inner loop requires instructions from the outer loop to initiate keystrokes. The instructions must include those associated with error correction response - i.e., pressing down of the backspace as well as the post-error letters that follow it. According to this interpretation, the outer loop must detect errors before they can be corrected via backspace. As will be outlined in the Current Study section below, this is an important point to remember to understand the motivation behind the current study in general, and our hypotheses more specifically.

1.6 Current Study

To the best of our knowledge, how error correction via backspace fits within the HCT framework at the lower level (inner-loop) has not been studied before. Although the fact that error detection can occur at the inner loop level is well-established, previous studies have not concentrated on the correction of errors at this level. In this respect our study will be exploratory in scope.

The current study is designed to test how error correction via backspace is implemented within the HCT (Logan & Crump, 2011). Our hypotheses related to outer- and inner-loop processes were tested using three measures (i.e., dependent variables): error awareness response, PES, and error correction via backspace in an attempt to test the validity of the below expectations. The error awareness response is an index of error detection at the outer loop level, while PES is an index of error detection at the inner loop level. The visual feedback coming from the screen plays a key role in detecting errors at the outer loop level (Logan & Crump, 2011; Snyder et al., 2015). Visual feedback was also manipulated to control the availability of feedback at the outer loop level. In other words, our independent variable was the presence of visual feedback: In one condition, participants' entries appeared on the screen and in another condition they didn't. By this way, it was expected that the only source of feedback (when the entries did not appear on the screen) would be the somatosensory feedback that came from fingers (or the inner-loop) to detect and correct errors. However, participants were required to report if they made an error after each trial in both conditions (error awareness responses).

If error correction (using the backspace) probability is found to be associated with indices of outer loop processing, this would support the idea that outer loop contributes to error correction. On the other hand, if the rate of pressing backspace is related to PES, then this would support the hypothesis that error correction is associated with inner loop processing.

1.6.1 Hypotheses

The hypotheses 1-3 test the proposition that the outer loop controls error correction and that inner loop (the slave system for the outer loop), can't initiate error correction without being instructed by the outer loop. Remember that the only source of feedback available to the outer loop is visual feedback, and according to the HCT (Logan & Crump, 2011) the outer loop doesn't receive information from the inner loop (i.e., that inner loop is "informationally encapsulated"). Hypothesis 4 tests the idea that the outer loop uses somatosensory feedback from fingers or input from the inner loop for error monitoring (i.e., that it is not informationally encapsulated). The hypotheses in the present study were as follow;

Hypothesis 1: There will be no error correction when the outer loop has no feedback (in the no visual feedback present condition).

Hypothesis 2: There will be no error awareness when the outer loop has no feedback (*“Sure Error” EAR rate following errors will be the same as that following correctly typed trials in no VF condition*).

Hypothesis 3: The rate of error correction and explicit error awareness will be similar when there is no feedback to the outer loop (*rate of corrected errors and rate of “Sure Error” error awareness response in errors will be the same in the no VF condition*).

Hypothesis 4: If it is the feedback from fingers or the inner loop that drives error detection at the outer loop, “sure errors” should be associated with larger PES than errors with smaller degrees of explicit error awareness (see grey dashed lines Figure 1).

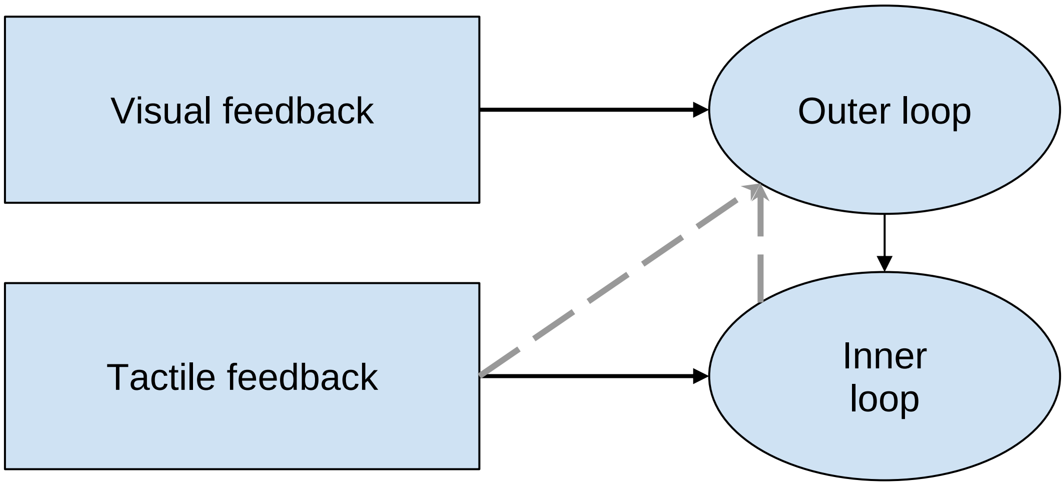

Figure 1: Figure showing the feedback the outer and inner loops have. According to the Hierarchical control theory, the outer loop only receives visual feedback from the screen and hands, whereas the inner loop receives somatosensory feedback only from the fingers. These inputs are represented in the figure using solid black lines. The current study is testing whether the outer loop can receive somatosensory feedback directly from the hands, or signals from the inner loop. These hypothetical signals are shown in the figure using dashed grey lines.

Chapter 2

METHOD

2.1 Participants

After the ethical application was approved from Eastern Mediterranean University, Research and Publication Ethics Board - Psychology Sub-Committee, a total of 25 participants were recruited. Five participants were removed due to hardware problems. Of the remaining 20 participants, 10 were males and 10 were females (mean age = 24.40, *SD*= 5.85, age range= 18-46). Participants were recruited using the convenience sampling method. The native language of the participants was Turkish; all of them had normal or corrected to normal vision and no psychological problems. The mean baseline typing speed of the participants was 38.60 words per minute (WPM) (*SD*=14.05), the mean of error rate was *M*= 32.73% (*SD*= 0.55) and 95% of the participants were right-handed (only one participant was left-handed).

2.2 Design

Dependent Variables: The dependent variables used in our analyses were post-error slowing, error awareness response and error correction via using backspace.

Post-error slowing (PES) is calculated by comparing the typing speed of the letters that follow the error to those that precede it. More specifically, it is calculated by averaging the IKIs of the two keypresses that follow an error and subtracting the IKI of the letter that precede it. IKI stands for inter-keystroke interval. IKI of a key press is the time elapsed between that key and the key that precedes it. PES is traditionally used to index error detection at the inner loop. Errors that are associated with significant PES are assumed to be detected at the inner loop level, and those that are not associated with post-error slowing are not (Logan & Crump, 2011).

Error awareness response was measured by asking participants whether they made a mistake after typing each word (i.e., at the end of each trial). In the current study the error awareness of participants was measured using a 5-option scale. This method was chosen because of its similarity to previous studies studying error awareness in typing (Snyder et al., 2015). Five options were available on the screen and these options were arranged in a scale from 1 to 9. The participants had to press a number based on their level of explicit error detection: (1) I'm sure that I made an error, (3) I think I made an error, (5) I'm not sure whether or not I made an error, (7) I don't think I made an error, and (9) I'm sure I haven't made an error. These options were counterbalanced across participants i.e., half of the participants received the above options and half received the reverse options, for example, option 1 became what option 9 used to be (see Figure 2). Counter-balancing was introduced to balance out any bias or tendency participants might have towards pressing keys on one side vs. the other (i.e., numbers on the left or right side of the keyboard).

Error awareness response is used as an index of error detection at the outer-loop. Errors that are followed by "Sure error" error awareness response are associated with strong explicit error detection at the outer loop level, and those associated with "Sure Correct" response are associated with no error detection at the outer loop level.

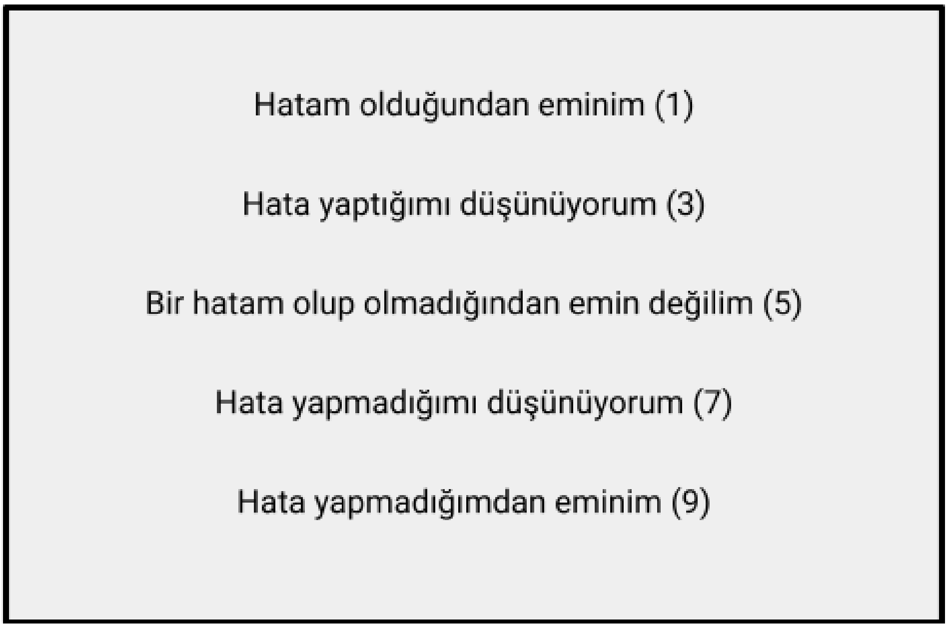

Figure 2: Figure showing the EAR.

Error correction in a trial is indexed by the pressing down of the backspace following an incorrect keypress. One of the primary aims in the study is to investigate the involvement of the inner and outer loops in triggering error correction.

Independent Variable: The only independent variable that we manipulated was the visual feedback. In one condition, participants were provided with visual feedback about their typing performance. What they have typed appeared under the word presented, and in a second condition it wasn't. All participants typed under both conditions. The order of visual feedback conditions was counterbalanced across participants to minimize order effects. By manipulating visual feedback, we attempted to manipulate input to the outer loop.

2.3 Procedure

The participants were tested individually in a quiet room. Once the participant agreed to participate in the study, the aims and the procedure of the current study were explained verbally. The informed consent has also been given verbally. Participants were asked and given time to adjust their position so they were sitting at a comfortable distance to the monitor and keyboard.

Then an online typing task was introduced to record their baseline typing skill (error rate and typing speed in words per minute). The baseline task has been carried out by using this website: “https://10fastfingers.com/typing-test/turkish”. In the baseline tasks, the participants were requested to type as many words as they could type in one minute. After the baseline test, there were 3 parts to the study, all conducted using MATLAB. Collection of demographic information, practice trials and experimental session, in that temporal order. Demographic information such as age, gender, handedness, typing speed, typing error rate, presence or history of mental or neurological problems were collected using a survey using MATLAB. Following this, 6 practice trials have been carried out. These practice trials were identical to the trials used in the experimental session except the words used for the practice trials were not used in the experimental session.

In the experimental session, participants were asked to type words (between 5 to 8 characters long) presented on screen, correcting any errors by using the backspace button, and reporting whether they made an error or not after typing each word under both visual feedback conditions. Each trial began with the presentation of a fixation cross (a “+” written in Arial font with size 30), which stayed on screen for 500ms. As soon as the fixation cross disappeared the word to be typed was presented, and stayed on screen until the participant pressed the “enter” key indicating they completed that trial. Error awareness responses appeared on screen 100ms after the participant pressed the “enter” key. The next trial started 1000ms after the participant made an error awareness response.

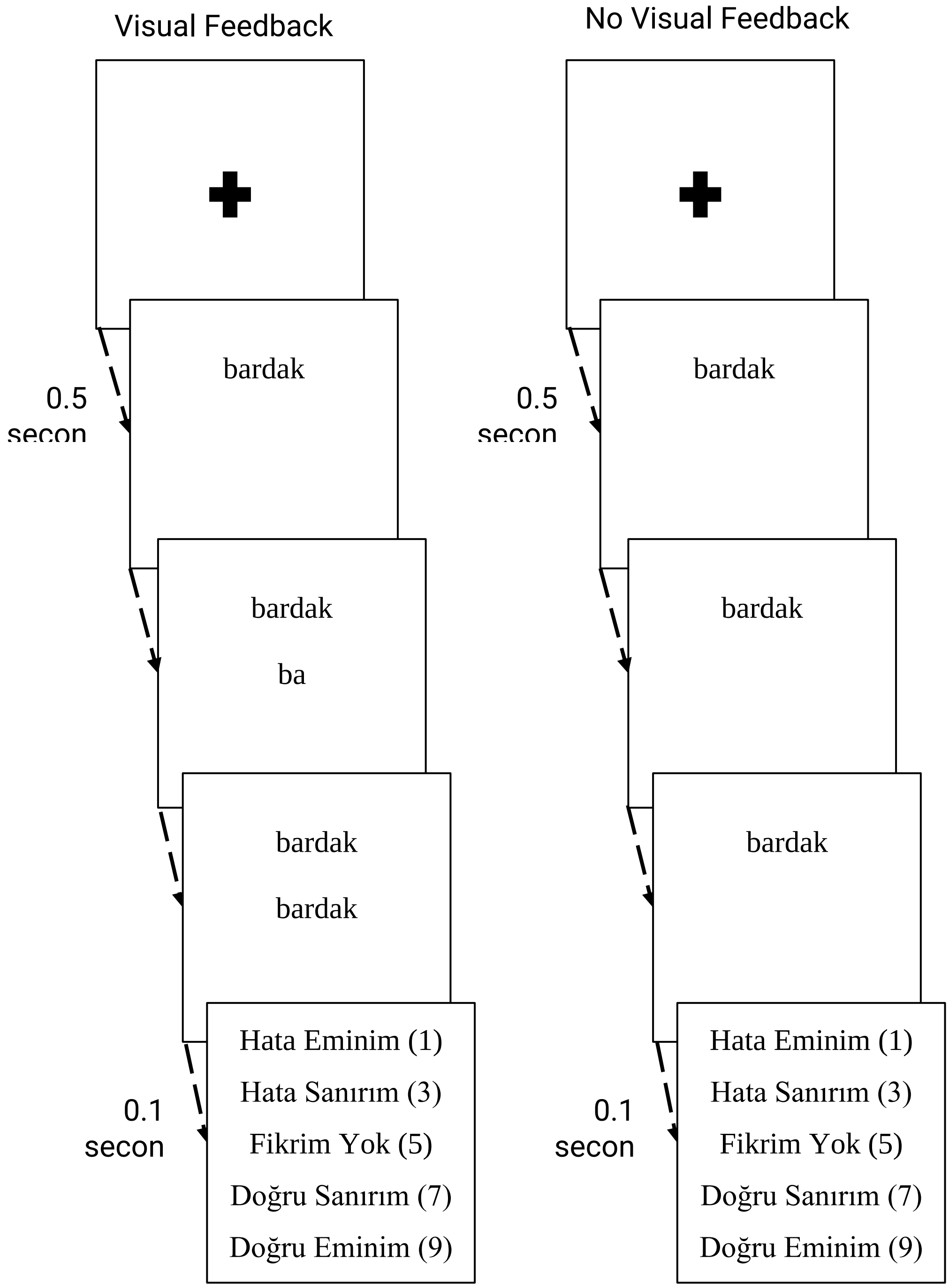

Figure 3: Figure showing the progression of trials in each visual feedback condition. The “+” symbol was followed by the word to be typed. After the participant finished typing the word, then they had to press the ENTER button to continue to the error awareness response section.

Participants were required to type each word as quickly and accurately as possible.

The duration to complete the whole experiment relied on the participant's typing speed, the total time needed to complete the experiment was approximately 40-50 minutes. At the end of the experiment, a debriefing was given verbally to all participants. In addition to that all related questions were answered and participants were thanked for their contribution. There were no incentives for participation.

2.4 Stimuli

Participants were tested individually and in a quiet room. Typists used a 64-bit Monster Gaming Laptop, with 16GB RAM running Windows 10 Pro. Stimuli were presented on this laptop's 15.6-in colour monitor. Keypresses were recorded on an additional standard QWERTY keyboard connected to the computer by a USB port. The stimuli were 600 five-to-eight letter words taken from a children's books (Turkish translation of The Little Black Fish (Beh-Rang, 1968/2016, Treasure Island (Stevenson, 1883/2007), Tom Sawyer (Twain, 1876/1995). Software used to present instructions, words to be typed and record all responses and error awareness responses were MATLAB R2018a © using functions included in the Psychtoolbox extension (Brainard, 1997; Kleiner et al., 2007; Pelli 1997). Words have been divided into 6 blocks of 100 words. The frequency of each word length (five-to-eight letter words) was equally distributed across blocks. To be more specific, 50%, 26%, 17% and 7% of the trials in all blocks presented 5, 6, 7, and 8 letter long words, respectively. The words were presented in black 30-pt Arial font on a 34.4 x 19.5 cm white background.

2.5 Analysis

IKI distributions of each participant were visually inspected in order to identify any participants whose typing ability was visibly different from the others, using histograms and 1st, 50th and 99th percentiles. While this method didn't reveal any outliers, it was found using this method that there were hardware issues that lead to the collected data to be unreliable (i.e., the IKI distributions were binned, which is an indicator of hardware failures during data collection). Because of this problem, five participants' data were removed from analysis. After the IKIs of the remaining participants were calculated, IKIs slower than 1500ms were removed from the analysis.

In order to calculate PES, the IKIs of two keypresses immediately following the erroneous keystroke (E+2 and E+1) were averaged and subtracted from IKI of the key-press preceded the erroneous key-press (E-1). But when the data were analysed, it was clear that PES were not equally distributed across error awareness responses. There were large differences in the number of observations among different error awareness responses (Table 5). PES was possible to calculate in trials associated with "Sure Error" error awareness response in all participants. However, the number of trials associated with other error awareness responses where the calculation of PES was possible was very low. Due to frequency differences between these options, PES was calculated but comparing PES across error awareness responses was not possible.

Chapter 3

RESULTS

3.1 Descriptive Statistics

All statistical tests were conducted using Statistical Package for Social Sciences (SPSS), version 23. The mean and standard deviation of error rate, IKI, error correction rate, and EAR ("Sure Error" response) for each visual feedback condition is presented in Table 1.

Table 1: Mean and standard deviations of error rate, IKI, error correction rate and EAR (Sure Error response) on feedback conditions

Variables	Visual feedback condition		No Visual Feedback condition	
	M	*SD*	*M*	*SD*
Error rate	13.73%	7.17%	10.62%	4.72%
IKI	233.75ms	67.33ms	237.03ms	70.76ms
Error Correction rate	83.26%	12.00%	63.95%	19.30%
EAR (Sure Error response)	90.08%	15.21%	67.70%	25.11%

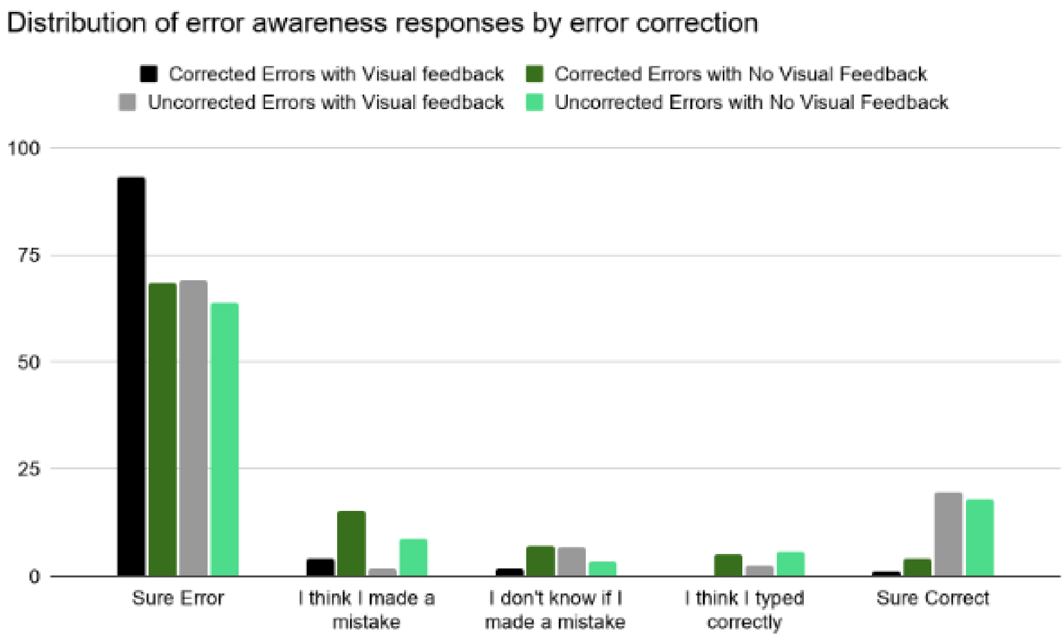

Figure 4: Shows the distribution of error awareness responses by error correction for visual feedback conditions.

3.2 Error Correction

First it was expected that there would be no error correction if the outer loop had no feedback from the screen. Therefore, the error correction rate when there is no error (i.e., number of trials where the participants used the backspace button without making an error divided by all the trials where there was no error) was compared to the error correction rate when there was an error (the number of corrected errors divided by all errors).

Since the distribution of the error correction rate when there is no error and there is an error was not normally distributed (Shapiro-Wilk test for there is no error: W=0.84, p=0.004, for there is an error: W=0.90, p=0.047), a Wilcoxon signed rank test was performed instead of a paired sample t-test. The results showed that pressing the backspace is much more likely following an error compared to when there is no error (Z=-3.92, p<0.001). The “error correction” rate in trials with and without an error are shown in Table 2.

Table 2:Descriptive Table showing the probability (%) of pressing the backspace when there was a typing error in the trial vs when there was no error.

Trial	25^{th} Percentile	50^{th} Percentile	75^{th} Percentile
No Error	0	0.38	0.76
Error	53.33	66.19	77.45

3.3 Error Detection

In the second hypothesis, it was expected that if the outer loop had no feedback from the screen, there would be no error awareness. The rate of “Sure Error” response following correct trials was compared to the rate of “Sure Error” response following error trials. Both variables were taken when the participant had no visual feedback from the screen.

The distribution of the rate of “Sure Error” responses following correct trials and the following error trials were not normally distributed (Shapiro-Wilk test for the following correct trials: W=0.36, p<0.001, that for the following error trials: W=0.93, p=0.150), a Wilcoxon signed ranks test was carried out. The results showed that there is a significant difference between the “Sure Error” responses following correct and error trials (Z=-3.92, p<0.001). The average proportion of “Sure Error” responses and related statistics were presented in Table 3.

Table 3: Descriptive Table shows the probability (%) of selecting “Sure Error” response following correct trials vs following error trials

Source	25^{th} Percentile	50^{th} Percentile	75^{th} Percentile
Correct Trials	0	0	0.38
Error Trials	52.22	64.02	93.28

3.4 Error Correction and Error Detection

In the third expectation, it was hypothesized that there would be no significant difference between the error correction rate and the explicit error awareness when there was no visual feedback provided.

The distribution of error correction and the error awareness responses were not normally distributed (Shapiro-Wilk test for the error correction: W=0.90, p=0.047, that for the error awareness responses following errors: W=0.93, p=0.150). A Wilcoxon signed ranks test was conducted to see if there is a difference between error correction and error awareness responses in non-visual feedback condition. The results indicated that the error correction and explicit error awareness responses were similar, i.e., there was no significant difference between the two variables (Z=-1.50, p=0.133). We failed to find statistical evidence to reject the null hypothesis that the two proportions are different. For the third expectation the null hypothesis could not be rejected. To check whether our non-significant hypothesis was because of a lack of statistical power, a post hoc power analysis was carried out with using G*Power (Faul et al., 2007; Faul et al., 2009). The effect size was 0.18, α error probability = 0.05, the total sample size was 20, and two-tailed was selected. The power was calculated to be 0.12. Average proportion of the error correction and the error awareness response and related statistics were presented in Table 4.

Table 4: Descriptive Table showing the percentile values for error correction and EAR in both no visual feedback conditions

Source	25th Percentile	50th Percentile	75th Percentile
Error Correction	53.33	66.19	77.45
EAR	52.22	64.02	93.28

3.5 Error Correction at lower-level

In the last hypothesis, it was expected that if it it's the feedback from fingers (or inner loop) that drives error detection at the outer loop, "Sure Errors" should be associated with larger PES than errors with smaller degrees of explicit error awareness. PES was not sufficiently distributed across other EAR, and therefore the fourth analysis could not be carried out. In the current study, PES data were mostly collected from trials where they responded to the "Sure Error" option. The other options have few numbers of data points that make a comparison impossible. In Table 5 the number of data points gathered from each option, and its corresponding average values and standard deviations scores were presented. This is why further analysis of PES was not possible to carry out.

Table 5: Descriptive Table showing the average number of data points (*M*) on which the mean PES is calculated for each participant. Column *N* shows the number of participants who contributed at least one data point to the calculation of this average

Measures	*N*	*M*	*SD*
Sure Error	20	37.40	21.58
I don't know	5	0.50	1.10
Sure Correct	14	1.75	1.92

Chapter 4

DISCUSSION

The current study aimed to test how error correction via backspace is implemented within the HCT (Logan & Crump, 2011). Our results suggest errors can be detected and corrected in the absence of visual feedback. This may be caused by error detection and correction within the inner loop or by the error detection and correction within the outer loop receiving feedback from the fingers when visual feedback from the screen is not available. While our analyses can't rule out the possibility that error correction takes place within the inner loop, they are more supportive of the proposition that the outer loop can utilize non-visual feedback to command the inner loop to initiate error correction.

To our knowledge, this was the first study to attempt to investigate the correction of errors separately at the inner and outer loop levels. According to HCT, the outer loop relies only on information which comes from the screen. Error detection at a higher level does not depend on information from the fingers or the inner loop because the inner loop is "informationally encapsulated" (see Fodor, 1983; Logan & Crump, 2011). Thus, within the HCT framework, in the visual feedback condition, both the outer loop and the inner loop contribute to error-detection-related processes while in the no visual feedback condition, only the inner loop should be able to contribute to error detection related processes.

Previous studies have shown that error detection can occur at a lower level but have not focused on error correction at this level (Logan & Crump 2010; Snyder et al. 2015). Crump and Logan (2013) stated that the implicit error detection capabilities emerge and become automatized as a by-product of explicit monitoring throughout skill learning. In our understanding of the HCT, inner-loop, a “slave-system”, should be unable to correct errors by pressing any key unless instructed by outer-loop. Rather, initiation of key-presses depends on the commands from the outer loop all the time. Our results do not rule out the possibility that it is the outer loop that instructs the inner loop to press the backspace, and in fact are compatible with such a hypothesis. However, this interpretation would violate some of the assumptions of HCT. Namely the assumption that the outer loop has no information about what the inner loop is doing (i.e., the idea that the inner loop is “informationally encapsulated”) and that the outer loop does not receive somatosensory or kinaesthetic feedback from the fingers. Next, we discuss these possibilities in relation to our hypotheses.

Our first hypothesis was that there would be no error correction behavior if the outer loop had no feedback about errors from the screen. However, it was found that individuals can engage in error correction behavior even if there is no visual feedback to the outer loop. The hypothesis was rejected. Secondly, it was hypothesized that there would be no error awareness when the outer loop has no feedback from the screen. Results have shown that the individuals can become consciously aware of their errors when there is no feedback to the outer loop. This hypothesis was also rejected. Results showed that individuals can become consciously aware of their typing errors even if their typings do not appear on the screen.

In the third hypothesis, it was argued if both error awareness and error correction without visual feedback rely on the same process (i.e. the outer loop, as proposed by the HCT), then there should be no significant differences in rate of explicit error awareness and rate of error correction in the absence of visual feedback. The findings showed that there were indeed no significant differences between rates of error awareness and error correction behaviour in no visual feedback condition. Thus, we failed to reject the null hypothesis that error awareness and error correction rates would be similar in the absence of visual feedback. Therefore, it is plausible that the outer loop is indeed controlling error correction (i.e., backspace presses) when it has no input from the screen.

In the fourth hypothesis, it was intended to test the proposition that the outer loop could use somatosensory feedback from the fingers or input from the inner loop for error monitoring when there is no visual feedback available. So, the expectation was that if it is the feedback from fingers or the inner loop that drives error detection in the outer loop, "Sure Errors" should be associated with larger PES than errors with smaller degrees of explicit error awareness. For the last hypothesis PES were calculated for trials labelled “Sure Error” by the participants, but we found that the number of participants who had used other awareness responses (e.g. “May be Error” or “May be Correct”) was too small to conduct any reliable statistical comparisons (see table 5). That's why this hypothesis could not be tested.

Overall, our analyses supported the idea that both error correction and error awareness can be carried out in the absence of visual feedback, and that both rely on the outer loop receiving feedback either from the inner loop or from the fingers. Next, we discuss our findings in relation to studies that had similar research questions.

Using a similar design, Snyder et al. (2015) also manipulated the visual feedback from the hands and the computer screen of participants as they typed 5 letter words: In a 2x2 design, visual feedback from the hands (present or not) and the screen (present or not) was controlled. In their study, participants' conscious error awareness was measured with two options: "Y" button was used to report they had made an error and "N" to report they hadn't.

They found that visual feedback from the screen and hands did not affect the PES (an index of error detection at the inner loop level). However, in conditions where visual feedback from the screen was not echoed, the rate of explicit error detection was lower. Our study supported the findings of Snyder et al. (2015) in that explicit error ownership of our participants was more accurate when the keystrokes were echoed on the screen than when they were not as well (Table 1). The authors explain this finding by proposing that visual feedback from the screen is a crucial source of information for explicit error detection (Logan & Crump, 2010, 2011; Long, 1976; Rabbitt, 1978; Rieger et al., 2011).

Snyder et al. (2015) explained that their participants were aware of their errors in the no visual feedback condition in the following way: When they compared the overall typing speed in different visual feedback conditions, they found that participants typed significantly slower in the no visual feedback condition, compared to visual feedback condition. In other words, in trials where there was no visual feedback, the outer loop slows down the execution of key-presses by the inner loop, so it can check for the accuracy of each key-press executed by the inner loop one by one, relying on tactile feedback from the fingers (Logan & Crump, 2009; Snyder & Logan, 2013; Tapp & Logan, 2011). Although their study didn't address the implementation of error correction directly, it is important in showing that error detection, a necessary step for error correction, is related to both visual and tactile feedback.

Data from our experiment don't support the exact finding related to the outer loop slowing down the inner loop to monitor each key-press. We found that the participants made significantly more errors in the trials where visual feedback was presented and there were no significant differences in terms of IKIs among the two visual feedback conditions. These contradictory findings may be due to a number of methodological differences between the two studies which we describe below.

When two sampling techniques of studies were considered; in the current study participants were selected by convenience sampling and there was no requirement for prior experiences with typing e.g., formal typing training. However, the participants in the former study were required to have completed a formal typing training in the past. Also, when typing speed and accuracy rate were compared before the analysis, participants in the previous study showed significantly better typing performance than current study participants (76.5 WPM vs. 38.60 WPM, and 91.9% mean accuracy vs. 67.27% mean accuracy). Therefore, the findings of the current study could not reject the proposition that the outer-loop adjusts the timing of the inner-loop to monitor keystrokes in conditions where visual feedback was not echoed. This could be due to the fact that the participants in the current study were much less skilled typists than the participants in Snyder et al., (2015) i.e., the outer loop' command (slowing the keystrokes) may not be apparent due to the already slow typing speed of current participants.

In addition to examining visual feedback conditions on typing behaviour, one study investigated the association between error correction responses and error-related behavioural and EEG variables (Kalfaoğlu et al., 2018). In this study, the participants did not receive any feedback from the screen, and their hands were covered by a card-box. The authors described that error correction could rely on the inner loop processing since their participants could detect and correct most of their errors without any visual feedback to the outer loop. Further, they showed that an electrophysiological index of implicit error detection, the error related negativity (ERN) was predictive of error correction. The authors stated that it was possible to make error correction at the inner loop level since the outer loop did not obtain information from the feedback coming from the screen. Kalfaoğlu et al., (2018) suggested that an alternative explanation was also possible: Although the outer loop relies on visual feedback whenever it is available; both visual and tactile feedback might be used to detect and correct errors when it is required.

Another study related to error correction outside of typing conducted by Ficarella et al., (2019) used another experimental task i.e., Simon Task (Simon, 1990) to compare the aware and unaware partial errors to get better understanding about their respective contribution to post-partial error-slowing (PpES) and to study relationship between electrophysiological measures such as ERN and error related positivity (Pe for short, an index of conscious error awareness, Overbeek et al., 2005, Murphy et al., 2012), and error correction processes. The partial errors were defined as subliminal muscle activations in the hand responsible for making the wrong response prior to correct behaviour being performed (Eriksen et al., 1985; Smid et al., 1990) in response to a given stimulus.

Participants' conscious awareness of partial errors was measured orally on a visual scale ranging from 1 to 6, where 1 represented no awareness of a partial error and 6 represented certainty of partial error commission. To calculate PpES, Ficarella et al. subtracted the RTs in the pure correct trials that follow pure correct trials from pure correct trials that followed aware partial errors and unaware partial errors.

In their analysis, they reported that there was a significant association between overt errors and a Pe. However, their findings showed that no Pe was observed right after partial errors (see also Burle et al., 2008; Ficarella et al., 2019; Vidal et al., 2000), whether these errors are consciously detected or not. The authors argued that the absence of Pe on unaware partial errors fits with the view that these unaware partial errors have been corrected without conscious awareness. Yet the absence of Pe, an EEG index of conscious error awareness, on aware partial errors seems more contradictory (Ficarella et al., 2019).

Ficarelle et al., (2019) demonstrated that the participants became aware of these partial errors after they have been corrected. The authors pointed out that corrective responses alone do not play a key role in awareness. In brief, this supports the view that cognitive control (error correction) can take place without conscious awareness (van Gaal et al., 2008; 2009). These findings have led us to think that in our study, typists may have corrected their typing errors without these errors being consciously detected. In other words, it is possible that at least in some of the trials the backspacing may take place without explicit error ownership.

The current study has some limitations, one of the drawbacks was found when the data is collected. The error awareness responses were arranged from “Sure Error” to “Sure Correct” (see Figure 2). This created a problem in analysing the results. During the debriefing sessions we found out that some participants chose the “Sure Correct” error option after correcting an error they typed. They assumed that having corrected an error also counted as correct typing. In the same case, other participants may have chosen the "Sure Error" option, because compared to the trials where an error was never made, this has one error that was corrected. Because of the above problem, we cannot confidently distinguish between “Sure Correct” responses that indicate not becoming aware of an error vs. becoming aware of having committed (and corrected) an error.

This makes it difficult to test hypotheses that are more directly related to the idea that “error detection dissociates from error correction” by including trials where the “Sure Correct” option was selected following errors. This drawback is important, and forthcoming researchers who are interested in HCT (Logan & Crump, 2011) in error related issues need to be aware of this problem. To prevent this above dilemma, the future researchers need to explicitly instruct the participants to select the “Sure Error” option after they become consciously aware of their errors (even after error corrections), and “Sure Correct” option only after trials where they are sure they haven’t committed any errors, and not after correcting their errors. It was one of our interests to test Ficarella et al., (2019) findings using typing behaviour. If this limitation would have been controlled, we would be able to test the association between the error correction and the participants' failure to explicitly report errors in the typing process.

Another limitation is that, due to the data point differences in error awareness responses, the PES following each error awareness response could not be compared. Participants were much more likely to select “Sure Error” and “Sure Correct” options compared to the other responses that indicate uncertainty. To prevent this drawback, the number of trials can be increased. In the current study there were 600 hundred Turkish words, this number can be extended to 800 or more to allow a larger number of instances in each category. Alternatively, the participants can be encouraged to use these options more liberally, whenever they are not absolutely sure about the accuracy of their performance. If we had a reliable PES from each error awareness response option then we could also compare the PES in the trials that the participants made an error correction (whether these errors are explicitly detected or not) to those that the participants' response of Sure Error option (errors without correction). Then we could argue that the PES was one of the key factors that led the inner-loop to correct errors in the trials where visual feedback was not present.

Another limitation was related to not covering the hands of participants. Sight of the hands could provide feedback to the outer loop. In previous studies, the visual feedback coming from the hands were controlled by using a card-box (Snyder et al., 2015; Kalfaoğlu et al., 2018). Even though the participants were explicitly instructed (and warned when necessary) to look at the screen and not to the keyboard while they were typing, we cannot eliminate the possibility that visual feedback from the hands were not used to detect errors at the outer loop. In order to solve this issue in future research, the participants' hands can be covered by a card-box.

Another limitation was related to the low power of the analysis we used to test the third hypothesis. The power analysis suggests that our null finding is far from being conclusive about the relationship between error correction and error awareness. Although the results from our first two analyses suggests the outer loop is capable of generating both error awareness and error correction, it is still possible that mechanisms involved in error awareness and error correction are separable. For example, there might be some trials that the participants corrected their errors where they failed to report explicit error awareness (due to the first limitation, we couldn’t analyse this proposition) and vice versa. This proposition was also supported with Ficarella’ et al., (2019) findings i.e., it was found that error awareness did not play a key role in corrective actions.

Another recommendation for other researchers interested in recording typing performance using the method described here is that they ensure their laptops are plugged in during data collection. Data from some participants could not be used because we found that the frequency distribution of IKIs from these participants suggested that the data collection speed of the hardware couldn’t catch up with the typing speed of the participants. We found that this problem was present in data collected during testing sessions with the laptop unplugged (i.e. running on batteries only).

One outstanding question that remained regarding the source of the information that the outer loop uses to detect and correct errors in the absence of visual feedback condition is this: Did the outer loop specifically use the outcome of the error detection processes within the inner loop or direct tactile feedback from the fingers? These questions could be investigated by future researchers.

4.1 Implications

Maintaining the ability to type as quickly and precisely as possible is a key demand in today's world. For example, there is a growing need for workers to complete their tasks on the basis of the common use of computers in the work environment as accurately and quickly as possible. In addition, typing skills have a direct effect in almost all work settings and can boost productivity at work. The present study sheds light on the typing performance of individuals in order to gain insight into typing errors and corrective processes. For this reason, the recommendation from the current study is clear; if the purpose of the typing is to produce outputs without errors for a given time, both loops must receive feedback without any interruptions or manipulations. In other words, the individual needs to pay attention to feedback coming from the screen and the fingers in order to produce error-free papers.

Another implication of the current study can also be adapted to other controlled actions e.g., playing an instrument. Logan and Crump (2011) stated that the hierarchical control can also be found in other skills and they argued that the ability to play music varies from typewriting (the performance itself is more critical, see Logan & Crump, 2011). For instance, the piano players elicit emotion by adjusting timing and pressing the keys softly or robustly (Repp & Knoblich, 2004; Shaffer et al., 1985). Logan and Crump (2011) argued that the outer loop is specifically involved with inner-loop procedures such as controlling the force of pressing down the keys, to ensure that they express the desired emotion. The instrument players may be more aware than the typists at the lower level (Logan & Crump, 2011). This suggests, therefore, that the current findings could be replicated with the use of other controlled behaviours and that the main idea of current research would be strengthened. Future researchers that are interested in piano playing can carry out a study using the same visual manipulations that we used in the typing method. By this way, they can provide more detailed information regarding error related processes within the HCT and how individuals detect and correct their errors at a lower level using other controlled actions.

4.2 Conclusions

To conclude, the current study aimed to show how error correction can be implemented within HCT. The current findings showed that individuals can perform error detection and error correction without feedback from the screen. The current findings suggest a modification in HCT, the individuals can make corrective actions using tactile feedback when there is no visual feedback presented. While the suggestion that error correction can take place without explicit error awareness, as suggested previously by Ficarella et al. (2019) and Kalfaoğlu et al. (2018) cannot be ruled out by our findings, the idea that the outer loop can receive feedback from the fingers is clearly supported by our findings.

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APPENDICES

Appendix A: Informed Consent

Doğu Akdeniz Üniversitesi
Eastern Mediterranean University

"Uluslararası Kariyer İçin"
"For Your International Career"

Psikoloji Bölümü / Department of Psychology

Psikoloji Bölümü

Doğu Akdeniz Üniversitesi

Gazimağusa, Kuzey Kıbrıs Türk Cumhuriyeti

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Web: http://brahms.emu.edu.tr/psychology

Performans Denetimi ile İlgili Bilişsel Süreçler *(Appendix A)*

Değerli katılımcı,

Araştırmaya katılmayı kabul etmeden önce, lütfen araştırma ile ilgili aşağıda bulunan bilgileri dikkatlice okumak için birkaç dakikanızı ayırınız. **Araştırma ile ilgili herhangi bir sorunuz varsa, aşağıda iletişim bilgileri olan araştırmacıyla iletişim kurabilirsiniz.**

Bu çalışma Yrd. Doç. Dr. Çığır Kalfaoğlu tarafından yürütülmektedir. Çalışmanın amacı hem davranışsal ölçümler kullanarak klavyede yazım esnasında örtük ve açık hata farkındalığında yer alan zihinsel süreçleri incelemektir. Çalışmaya katılımanız durumunda kısa cümleler yazmanız, yaptığınız hataları backspace kullanarak düzeltmeniz ve her bir cümleden sonra hata yapıp yapmadığınızı değerlendirmeniz istenecek. Çalışmanın 40-60dk arası sürmesi beklenmektedir.

Çalışmaya katılımınız zorunlu değildir ve katılmayı reddetme hakkına sahipsiniz. Çalışmadan, istediğiniz bir anda, açıklama yapmaksızın çekilme hakkına sahipsiniz. Araştırmadan çekilmeniz durumunda, elde edilen veriler araştırmada kullanılmayacaktır ve eğer isterseniz yok edilecektir. Eğer araştırmaya katılmayı ve tamamlamayı kabul ederseniz, veriler **gizlilikle** korunacaktır. İsminiz ve tanımlayıcı bilgileriniz, verilerin geri kalan kısımlarından ayrı olarak muhafaza edilecektir. Veriler, araştırma tamamlandıktan sonra en çok 6 yıl boyunca muhafaza edilecektir. Verilerin analizinden sonra, araştırma ile ilgili bir rapor yayınlanabilir. Dilerseniz çalışmanın sonunda hazırlanan raporun bir kopyasını araştırmacılardan temin edebilirsiniz. Eğer çalışmaya bağlı olarak bir sorun yaşarsanız Doğu Akdeniz Üniversitesi Psikoloji Bölüm başkanlığına başvurabilirsiniz (tel: +90 392 630 1389).

Gönüllü katılımınızı belirtmek için, lütfen bir soraki sayfada bulunan bilgilendirilmiş onam formunu imzalayınız.

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Appendix B: Debriefing Form

Doğu Akdeniz Üniversitesi
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Katılımcı Bilgi Formu *(Appendix B)*

Açık ve örtük hata farkındalığı ile ilgili zihinsel süreçerli incelemeyi hedefleyen bu çalışmaya katıldığınız için teşekkür ederiz. Araştırmanın hedeflerini açıklamayı amaçlayan aşağıdaki bilgileri okumak için lütfen birkaç dakikanızı ayırınız. Araştırma ile ilgili sorularınız varsa, aşağıda iletişim bilgileri olan araştırmacıyla iletişim kurabilirsiniz.

Çalışmamızın amacı örtük ve açık hata farkındalığını ayni çalışma içerisinde inceleyerek, ilgili teorilerin (örn. Hiyerarşik Kontrol Teorisi, Logan & Crump 2011) test edilmemis hipotezlerini test etmektir. Daha önce yapılan çalışmalar, örtük hadta farkındalığı ve açık hata farkındalığının birbirinden ayrışabileceğini göstermiştir (Logan & Crump 2010). Fakat daha önceki çalışmalar aöık hata farkındalığı olmadan örtük hata düzeltimi olup olmayacağını test etmemişlerdir. Amacımız, bu fikri kontrollü bir laboratuvar ortamında test etmektir.

Araştırmaya katılımınızdan sonra herhangi bir rahatsızlık veya sıkıntı duyuyorsanız ve bir uzman ile konuşmak istiyorsanız, lütfen DAÜ Psikolojik Rehberlik, Danışma ve Araştırma Merkezi (PDRAM, 0392 630 2251) ile iletişim kurunuz. Ayrıca araştırmanın kendisi ile sorularınız için araştırmacı (Çığır Kalfaoğlu, cigir.kalfaoglu@emu.edu.tr) ile de iletişim kurabilirsiniz.

Araştırmaya ayırdığınız zaman ve yaptığınız değerli katkıdan dolayı teşekkür ediyoruz.

Saygılarımla,

Yard. Doç. Dr. Çığır Kalfaoğlu

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Appendix C: EMU's Scientific Research and Publication Ethics Board Approval Letter

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Etik Kurulu / *Ethics Committee*

Reference No: ETK00-2019-0225 05. 11.2019

Subject: Application for Ethics.

RE: Assist. Prof. Dr. Çığır Kalfaoğlu
Department of Psychology

To Whom It May Concern:

On the date of **05.11.2019**, (Meeting number **2019/24-09**), EMU's Scientific Research and Publication Ethics Committee (BAYEK) has granted, Assist. Prof. Dr. Çığır Kalfaoğlu from the Department of Psychology to pursue with his work **"Error awareness dissociates from error correction"**. This decision has been taken by the majority of votes.

Regards,

Prof. Dr. Fatma Güven Lisaniler
Director of Ethics Committee

FGL/ns.

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