RUNNING HEAD: Deliberate Practice and Typing Proficiency

A Deliberate Practice Account of Typing Proficiency in Everyday Typists

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Abstract

The concept of deliberate practice was introduced to explain exceptional performance in domains such as music and chess. We apply deliberate practice theory to intermediate-level performance in typing, an activity that many people pursue on a regular basis. Sixty university students with several years typing experience participated in laboratory sessions that involved the assessment of abilities, a semi-structured interview on typing experience, as well as various typing tasks. In line with traditional theories of skill acquisition, experience (amount of typing since introduction to the keyboard) was related to typing performance. A perceptual speed test (digit-symbol substitution) and a measure of motor abilities (tapping) were not significantly related to performance. In line with deliberate practice theory, the highest level of performance was reported among participants who had attended a typing class in the past and who reported to adopt the goal of typing quickly during everyday typing. Findings suggest that even after several years of experience engagement in an everyday activity can serve as an opportunity for further skill improvement if individuals are willing to push themselves.

Keywords: Skill acquisition, Performance improvement, Abilities, Keyboarding, Goals

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Since the development and increased use of typewriters, applied researchers have been interested in various aspects of typing skill. Research has been conducted on diverse topics such as learning curves in the acquisition of typing (e.g., Chapman, 1919; Towne, 1922), selection of typing students based on ability tests (e.g., Flanagan, Fivars, & Tuska, 1959; Gronert, 1925), ergonomic issues concerning the optimal arrangement of keys on the keyboard (e.g., Fagarasanu, Kumar, & Narayan, 2005; Hirsch, 1970), and models describing the cognitive and motor processes involved in skilled typing (e.g., Gentner, 1987; Rumelhart & Norman, 1982; Salthouse, 1986; Shaffer, 1976; Shaffer & Hardwick, 1970). In the present study we use the domain of typing to assess factors that influence proficiency in activities which people have performed regularly, perhaps even daily, for many years. We examine typing skill with the goal to enhance theoretical understanding of skill improvement after the basics of this particular skill have been mastered. More specifically, we investigate the relative contributions of abilities, experience, and deliberate practice activities to typing proficiency in experienced but non-professional typists.

The concept of deliberate practice was first introduced to explain expert performance in domains such as music and chess (Charness, Tuffiash, Krampe, Reingold, & Vasyukova, 2005; Ericsson, 2006a; Ericsson, Krampe, & Tesch-Römer, 1993). The basic assumption is that an individual's level of performance in a particular domain is the result of effortful practice activities in which he or she has engaged in over the course of several years with the explicit goal of performance improvement. The task domain (i.e., typing) and participant sample (i.e., university students who have been using the keyboard regularly for several years) used in the present study seem well suited to enhance theoretical knowledge in the area of skill improvement for several reasons. First, we apply the concept of deliberate practice, which was originally developed to explain outstanding performance, to intermediate-level performance. Second, typing is a task domain that is less susceptible to selection and self-selection than some traditional domains of expertise research such as music or sports (e.g., Musch & Hay, 1999), because many people engage in typing for various tasks in education, on the job, and for personal use. Finally, interindividual differences in typing performance are relatively easy to measure objectively and reliably, which is a favorable task property when the research goal is to explain these differences (cf. Ericsson & Smith, 1991). In the following sections, we explain the concept of deliberate practice in more detail and discuss its implications for skilled typing performance. Before doing so, we briefly describe two alternative concepts that potentially contribute to the prediction of typing performance, namely, general and specific abilities as well as typing experience.

Abilities and Typing Performance

Several attempts have been made to identify general or specific abilities that predict typing performance in students after training, for the most part in the first half of the 20th century when typing was a major topic in vocational schools. Some researchers have concluded that there were no notable relations between typing performance and general cognitive abilities (Stedman, 1929) or motor skills (Kitson, 1927; Walker & Adams, 1934), while others found tapping speed and the ability "to carry on the process of substitution" (Tuttle, 1923, p. 177) to be related to typing performance—at least among novices after a semester of typing training (e.g., Flanagan et al., 1959; Gronert, 1925). Within Ackerman's (1988, 2000) framework, three types of abilities can be distinguished that may play a role during skill acquisition, namely, general cognitive abilities, perceptual speed, and psychomotor abilities. In the present study, we included one indicator variable representing each of these abilities and tested their relation to typing performance, namely, participants' SAT score as an indicator of general cognitive abilities, a digit-symbol test as an indicator of perceptual speed, and a tapping test as an indicator of psychomotor abilities. In operational terms, therefore, we tested main effects of SAT score, digit-symbol score, and tapping speed on typing performance.

Experience and Typing Performance

Many everyday skills, such as driving or cycling, as well as recreational games and sports can be acquired relatively easily within weeks or months, at least to an acceptable level of performance (Ericsson, 1996, 2006a). Skill acquisition in these domains can be described by traditional theories of skill acquisition which distinguish three stages to delineate how task performance becomes automatic through practice (Fitts & Posner, 1967). In the initial "cognitive" phase, individuals learn the underlying structure of the activity and develop strategies for the task. Performance in this phase is usually slow and error-prone. In the second "associative" phase, individual elements that are necessary for successful task execution become integrated into sequences of actions. Performance becomes faster and errors are reduced. Finally, in the "autonomous" phase, performance becomes more and more automatic and poses fewer demands on attentional resources; learners can perform the activity largely without thinking. In principle, once the autonomous stage is achieved, task performance (particularly in terms of speed) can be improved indefinitely, although the magnitude of improvement decreases with more practice (Power Law of Practice; Anderson, 1982). In other words, traditional theories of skill acquisition imply that high levels of performance can be achieved by engagement in an activity. According to these theories, when typists have to learn the assignment of keys to letters, performance may be slow and error-prone. However, the more a person engages in typing activities the number of errors are reduced and typing speed increased (cf. Gentner, 1988). In other words, amount of accumulated typing experience (i.e., the amount of text he or she has typed in the past) is related to an individual's typing performance. We included estimates of participants' accumulated amount of typing as well as typical amount of typing per week in the present study. In operational terms, we tested for main effects of estimates of overall amount of typing and typical amount of typing on performance.

Deliberate Practice and Typing Performance

Ericsson et al. (1993) introduced the term *deliberate practice* to describe focused and effortful practice activities that are pursued with the explicit goal of performance improvement. Deliberate practice implies that well-defined tasks are practiced at an appropriate level of difficulty and that informative feedback is given to monitor improvement. These activities can be designed by external agents, such as teachers or trainers, or by the performers themselves. Research conducted in several domains such as music (Ericsson, 2006a; Ericsson et al., 1993; Sloboda, 1996), sports (Helsen, Starkes, & Hodges, 1998; Hodges, Kerr, Starkes, Weir, & Nananidou, 2004), and chess (Charness et al., 2005), suggests that the amount of accumulated deliberate practice is closely related to an individual's attained level of performance.

When engaging in deliberate practice, individuals have to counteract the tendency to rely on generalized automaticity by deliberately refining and developing their skills (Ericsson, 1996, 2006a). In line with this claim, a large body of literature on the effects of goal-setting on performance suggests that challenging and specific goals encourage individuals to exert more effort and to optimize their task strategies, which in turn leads to improved performance beyond their current level (Locke & Latham, 1990). Although this literature is primarily concerned with goals set by external agents (e.g., supervisors), research indicates that the same mechanisms apply for self-set goals as well (Frayne & Geringer, 2000; Latham & Locke, 1991; VandeWalle, Brown, Cron, & Slocum, 1999). In addition, there are now large scale reviews which show that the relation between amount of accumulated professional experience and attained performance is low and sometimes even negative (Choudhrey, Fletcher, & Soumerai, 2005; Ericsson & Lehmann, 1996) and that improvements in performance can be attributed to practice activities meeting the criteria for deliberate practice (Ericsson, 2004; Ericsson, Whyte, & Ward, 2007). In the domain of work, Sonnentag and Kleine (2000) identified deliberate practice activities in insurance agents (e.g., mental simulations of difficult situations with clients) and found the number of times agents regularly engaged in such activities to be related to their job performance. Yet, the number of years of experience as an insurance agent was unrelated to performance.

When applying the concept of deliberate practice to intermediate everyday typing, a number of assumptions need to be made. One assumption concerns the extension of the theory, which was developed to explain excellent performance, to intermediate-level performance. For some domains, it may be argued, such an extension may not be justified. For example, existing research on chess indicates that beginning and intermediate chess players select their moves based on immediate goals, whereas expert chess players have more refined representations of the game situation which help them to select better actions (e.g., Charness et al., 2005). We suggest that for the domain of typing, however, there is no such qualitative difference between intermediate and expert performance and that the cognitive-motor mechanisms mediating typing performance in intermediate performers parallel those in expert performers, with the difference lying only in the efficiency of these mechanisms.

Second, the nature of the mechanisms which mediate typing performance needs to be specified. Research on typing skill has shown a strong correlation between typing speed and the extent to which typists look ahead in the text to be typed (eye-hand span). When skilled typists are prevented from looking ahead (as has been done in experiments systematically varying the preview), their performance advantage is reduced almost to the level of novice typists who do not rely on looking ahead (Butsch, 1932; Salthouse, 1984, 1986; Shaffer, 1976; Shaffer & Hardwick, 1970). Apparently, by looking farther ahead, skilled typists can prepare sequences of future keystrokes and move their fingers toward the corresponding keys well ahead of time (Legrand-

Lestremau, Postal, & Charles, 2006; Norman & Rumelhart, 1983). It therefore seems plausible to assume that the results of deliberate practice activities in typing are representations that enable such an anticipatory preparation of key press sequences.

Finally, we need to clarify the kind of activities that can be considered deliberate practice in everyday typists. Professional athletes, musicians, chess masters, or aspiring typing champions who are highly motivated to excel in their domain may be expected to devote several hours a day for many years to deliberate practice activities with the explicit goal of improving performance. However, everyday typists may not be expected to engage in more typing activities than those they need to complete their everyday typing tasks (e.g., class work, letters) or to explicitly adopt the goal to improve their typing skills as they work on their everyday typing tasks. We propose that everyday typists may engage in activities that resemble deliberate practice that everyday typists may or may not pursue and that can affect their typing performance, even if they do not explicitly adopt the goal of skill improvement. In particular, we propose that attending a typing class and adopting a speed goal during everyday typing meet the criteria of deliberate practice and may be beneficial to attain higher levels of typing performance in everyday typists.

Attending a typing class may benefit performance because efficient typing techniques are taught in class (such as touch-typing, in which the visual search of keys is replaced by a strict assignment of fingers to keys and in which typists rely on kinesthetic feedback; Cooper, 1983; Gentner, 1988; Yechiam, Erev, Yehene, & Gopher, 2003). In addition, they provide a setting in which the performance goals of typing speed and/or accuracy are explicitly emphasized and in which immediate feedback on goal attainment is given (e.g., typing drills and speed tests with immediate feedback on speed and accuracy). However, attending a typing class in itself does not necessarily constitute deliberate practice for all participants, as they can differ in their motivation to engage in effortful practice during class time. Also, typing classes are limited to a particular time period of several weeks or months. Further improvements seem most likely if typists use their everyday typing activities as a means to complete their typing tasks and at the same time as an opportunity to improve. We propose that everyday typists differ in the degree to which they explicitly adopt the subjective goal of typing fast while pursuing their everyday typing tasks. Adopting such a speed goal, in turn, helps to improve typing skills, as typists exert more effort during typing and optimize their techniques (cf. Latham & Locke, 1991). In sum, we expect everyday typists to benefit most from the combination of systematic training (i.e., attending a typing class) and the explicit goal of high performance while engaging in everyday typing. In operational terms, we expected an interaction effect of attending a typing class and the degree to which typists adopt a speed goal during everyday typing.

In summary, in the present study we investigate the relative contribution of abilities, amount of experience, and deliberate practice activities to the prediction of typing performance. To test these predictions, we use two dependent variables, namely, typing performance on meaningful text material and typing performance on nonsense text material. We use an aggregate measure derived from typing speed and accuracy on multiple typing tasks. It is important for ecological validity to include meaningful text material (i.e., meaningful words and sentences), as texts typed in everyday typing are usually meaningful. The inclusion of nonsense text material (i.e., isolated letters, syllables, and short words) may be informative for the assessment of typing skill because typing speed and accuracy on meaningful material may depend not only on typing skill itself but also on other abilities such as spelling and word knowledge. The more words a typist knows or the better the typist's spelling abilities the more likely it is for him or her to type these words quickly and accurately (e.g., Cohen & Wicklund, 1990; Limp, 1929), as the process of decoding the source material is speeded up (e.g., Gentner, 1988). However, for nonsense material it is not likely that spelling abilities or word knowledge is helpful for typing faster. In other words, we suggest that our predictions are subjected to a stricter test when typing performance on both meaningful and nonsense materials are considered as dependent variables in the analyses.

Method

Participants

Participants were 60 undergraduate students who received course credit for participation. About half of the sample was male (48.3%). Participants ranged in age from 18 to 31 years (*M* = 19.48, *SD* = 1.94). All participants had several years of experience with using the computer keyboard (Mean years since first use of a keyboard = 11.36, *SD* = 3.14, *Min* = 4, *Max* = 18). All participants reported to have permanent access to a computer; only one participant reported not to own a computer (Mean years since owning a computer = 4.23, SD = 3.47). The first language of all but one participant was English (this one participant grew up in the U.S.).

Procedure

Participants attended individual laboratory sessions that lasted approximately two hours. The sessions consisted of three sections. In the first section, ability tests were given to participants. In the second section, a semi-structured interview focusing on participants' typing experience was conducted. Finally, participants completed several typing tasks on a computer typing tutor which displayed the text that participants were asked to copy type.

Material and Measures

Ability Measures. As a proxy for general mental abilities, we used participants' SAT scores (Frey & Detterman, 2004). For 45 participants, official university records of SAT scores were available; for 11 participants (who had also given consent to access their records but for who records were not available), we used self-reported SAT scores; for four participants who had taken the ACT but not the SAT, we converted official ACT scores into SAT scores (Dorans, 1999). Where participants had completed scores for both measures, the correlation between official and self-reported SAT scores was high, ($r = .96$, $p < .01$, $N = 40$), indicating that self-reports were valid indicators. As a measure of perceptual speed, we used the Digit-Symbol Substitution subtest of the Wechsler Adult Intelligence Scale (Wechsler, 1998) in which numbers are to be substituted by specified symbols as fast and accurately as possible. Finally, we included tapping tasks to measure finger motor speed. Participants were asked to repetitively tap as fast as possible for 15 seconds with the right index finger, the left index finger, alternately with the left and right index fingers, and alternately with the index and middle fingers of both the right and the left hands, respectively, on specified keys of the keyboard. To increase reliability, the first two tapping tasks were repeated. We derived an aggregate measure of all tapping tasks by first calculating the mean of the two repeated tasks and then aggregating standardized scores of all five different tasks. Cronbach's α for the tapping tasks was .87.

Interview on Typing Experience. The main indicators of typing experience and deliberate practice were derived from a semi-structured interview that lasted approximately one hour. The interview consisted of three sections. The first section dealt with participants' current typing habits. Participants were asked what materials they had typed in the past four to six weeks (e.g., homework, papers, e-mails, instant messaging, internet shopping). For those materials they had typed, they were asked how many of them they had typed in the past week (e.g., how many homework assignments, papers, e-mails, instant messages) as well as how many text lines they produced when typing these materials. To increase the accuracy of estimates, participants were shown a sample double-spaced text page of 24 lines and a sample e-mail of six lines. Participants were also asked whether this past week they had reported on was a typical or non-typical week with regard to their typing habits. In case it was a non-typical week, participants were asked what material and how many lines they would type in a more typical week. Participants' estimates of text lines were summed across materials to represent the *amount of typing in a typical week* which we used as an indicator of typing experience. Finally, participants were asked to rate on a 10-point scale for each of the materials they regularly typed, how important typing speed is for them personally (i.e., to what extent do they adopt the goal "I want to type as fast as possible" when typing this particular material?). Answers to these questions were aggregated to represent *subjective speed goal* in everyday typing. Cronbach's alpha could not be calculated because participants differed in the material they typed regularly and thus in the items and number of items they answered. As a proxy, the Cronbach's alpha was .82 (N = 19) for the four materials that participants indicated that they type most frequently (class work, messaging, e-mails, and letters). Subjective speed goal in everyday typing was used as an indicator for deliberate practice.

The second section of the interview dealt with participants' past typing habits. The following questions were designed to assess the absolute amount of typing since participants had started to use the keyboard, with the goal to reduce recall errors which can affect this kind of retrospective recall (cf. Côté, Ericsson, & Law, 2005). First, we named several events that may influence a person's typing habits (e.g., having a computer in the household, getting a computer of one's own, getting internet access and an e-mail account) and asked participants whether these events had occurred in their personal typing history and, if so, at what age. In a next step, we asked participants for each event whether it was a transition point in that it had changed their typing habits significantly and we asked whether they could think of any other transition point we had not mentioned. Subsequently, we marked the transition points named by participants in a sheet that illustrated a time line ranging from 10 years to participants' present age. We then asked participants what materials they had typed between these transition points and let them estimate the number of text lines using the sample double-spaced page and e-mail. For example, if a 20-year old participant reported that he or she had started to type as a 10-year old and that getting a computer at age 14 and entering college at 18 years were transition points, we would ask for the time periods from 10 to 14 (onset of regular typing but before getting a computer), from 14 to 18 (after getting a computer but before entering college), and from 18 years (after entering college) to present. We calculated the *absolute amount of typing* based on participants' estimates of text lines and used this measure as an indicator of typing experience.

In the last section of the interview we dealt with participants' deliberate attempts to improve typing proficiency. We asked participants whether they had attended a typing class in the past and what was the content of this typing class. Initially, 46 of the 60 participants reported that they had attended a typing class in the past (most often because it was a school requirement or because a teacher or counselor had recommended the class, 78%). However, further prompting indicated that in many cases these were actually computer classes in which using the keyboard had been a minor topic. Based on participants' descriptions of the class content, we counted typing classes as such only if they mainly (80% or more of class time) comprised activities that emphasized typing speed and/or accuracy goals, namely typing drills, speed tests, or typing letters. This classification yielded 34 participants who had attended a *typing class* (dichotomous variable, yes/no; we also reran analyses with 75% and 85% of class time as cut-off points, and the results did not differ). In addition, we asked participants whether they had deliberately taught themselves how to type and, if so, what they had done to teach themselves. Only four participants had used a computer typing tutor or typing book to systematically teach themselves. As 3 out of the 4 participants had also attended a typing class, we refrained from including deliberate self-teaching in any further analyses. Attending a typing class was used as a second indicator for deliberate practice.

Typing Tasks and Typing Performance. To assess typing performance, we selected twelve typing tasks of different contents, with the goal to obtain a broad and representative measure of typing skill. All tasks were presented on a computer typing tutor that displayed a stream of text on top of the screen. Participants' task was to copy type this text as fast and accurately as possible within a predetermined time. The typed text appeared on the screen directly below the presented text. If participants made an error, the incorrect letter would be highlighted in red. To discourage correction of errors, the backspace key was removed from the keyboard. Typing performance was measured in net words per minute (net wpm). This commonly used measure approximates the number of correctly typed words in a minute (Gentner, 1988; Salthouse, 1986). It does not reflect the actual number of words typed correctly (which would make it dependent on the length of words in the source text), but is based on the average length of an English word, which is four letters, plus one space between words. To derive the net wpm measure, we first subtracted five characters per error (i.e., one average word of four letters plus one space) from all characters (gross number of characters) typed by a participant on a given typing task, which yielded the net number of characters. This net number of characters was then divided by five, which yielded the net words. Finally, we divided the net words by the length of the given task in minutes, resulting in the net words per minute. For example, if a participant typed 500 characters in a 2-minute typing task and made 10 errors, net wpm for this participant for this task would be ((500 – 10*5)/5/2 = 45.

The twelve typing tasks differed in whether the material was meaningful, in the amount of letters appearing in the text, and in length (1, 2, or 3 minutes, respectively). Two tasks comprised random letter combinations (e.g., xny anehn fe gjcjshrr) and two further tasks involved short words consisting of only letters of the middle row of the keyboard (e.g., flask half glass) or short orthographically and phonetically legal non-words with the same limited letters of the keyboard (e.g., falsa jassak). These four tasks had a length of one minute. The net wpm scores on there tasks were aggregated to represent performance on *nonsense material* (Cronbach's $\alpha = .96$). The other eight tasks included meaningful words that were randomly selected from commercially available typing tutors (1 minute), the repetition of a sentence that included all letters of the alphabet ("The quick brown fox jumps over a lazy dog.", 1 minute; cf. Salthouse, 1984), short and long frequent and infrequent words drawn from Kučera and Francis' (1967) frequency analysis of English usage (2 minutes each), brief paragraphs without any special characters or numbers derived from commercially available typing tutors (3 minutes), and paragraphs with numbers and special characters (e.g., % $ &) drawn from recent newspapers and magazines (3 minutes). The net wpm scores on these tasks were aggregated to represent performance on *meaningful material* (Cronbach's $\alpha = .98$).

Statistical analyses

As our study design involved a within-participant factor (i.e., performance on nonsense vs. meaningful material), we used a procedure described by Judd, Kenny, and McClelland (2001). This procedure is a simple generalization of analysis of variance and regression analysis with ordinary least squares estimation that allows simultaneously modeling within-participant and between-participant factors as well as their interactions. Therefore, significant effects can be interpreted accordingly (e.g., a significant interaction between a between-participant factor and a within-participant factor implies that the effect of the between-participant factor differs between the levels of the within-participant factor or vice versa). We plotted significant interactions using the regression-analytic techniques described by Aiken and West (1991; Cohen, Cohen, West, & Aiken, 2003), which make use of information from the full sample of participants. Where applicable, we used one-tailed testing for directional hypotheses. As measures of effect size, we calculated partial ε^2. This effect size represents an estimate for the proportion of explained variance of an effect after partitioning out the other effects in the model. In this respect, it is similar to partial η^2. However, in contrast to partial η^2, it is approximately unbiased in that it does not tend to overestimate the effect size (Fowler, 1985; Jaccard, 1998).

Power analysis

With the present sample size of 60, the power to detect a medium bivariate correlation of .30 was inadequate at .76 and the power to detect a large bivariate correlation of .50 was high at .99 (α = .05, one-tailed). However, our main analyses (i.e., hypothesis testing) were conducted using regression models. The power to detect a medium effect (Cohen's f^2 = .15) of one predictor in a regression model with three predictors was adequate at .84 and the power to detect a large effect (Cohen's f^2 = .35) of one predictor in a regression model with three predictors was high at .99 (α = .05; power calculations were conducted with G*Power 3; Faul, Erdfelder, Lang, & Buchner, in press).

Results

The descriptive statistics and bivariate correlations for the main variables are displayed in Table 1. The following sections report results for groups of multiple variables.

Abilities and Typing Performance

The effects of ability variables on typing performance were analyzed in a model with typing performance on nonsense versus meaningful text material as a within-participant factor and with SAT score, digit-symbol score, and tapping speed as between-participant continuous predictors. A main effect of the within-participant factor emerged; typing performance on meaningful material was better than on nonsense material (Table 2). For all of the ability variables there was a failure to reject the null hypothesis, but the SAT score interacted with the within-participant factor (Table 2), indicating that the effects of SAT score were significantly different for meaningful and nonsense material. As displayed in Figure 1A, the SAT score predicted typing performance for meaningful material (simple-slope $\beta = .27$, $t\ (56) = 2.07$, $p < .05$), but not for nonsense material (simple-slope $\beta = .05$, $t\ (56) = 0.35$, *ns*).

Experience and Typing Performance

The effects of experience variables on typing performance were analyzed in a model with typing performance on nonsense versus meaningful text material as a within-participant factor and the amount of typing in a typical week and the absolute amount of typing since onset of keyboard usage as between-participant continuous predictors. Besides the main effect of the within-participant factor (nonsense vs. meaningful text), there was a significant main effect for absolute amount of typing but a failure to reject the null hypothesis for amount of typing in a typical week (Table 3). In addition, the absolute amount of typing interacted with the within-participant factor (Table 3), indicating that the effects of absolute amount of typing were significantly different for meaningful and nonsense material. As displayed in Figure 1B, the absolute number of text lines predicted typing performance for meaningful (simple-slope $\beta = .37$, $t\ (57) = 2.96$, $p < .01$), but not for nonsense material (simple-slope $\beta = .16$, $t\ (57) = 1.21$, *ns*).

Deliberate Practice and Typing Performance

The effects of deliberate practice variables on typing performance were analyzed in a model with typing performance on nonsense versus meaningful text material as a within-participant factor and with the participation in a typing class and subjective speed goal as a between-participant predictor. We also included the interaction of the two between-participant predictors to model the combination of attending a typing class and subjective speed goal. Besides the main effect of the within-participant factor, subjective speed goal had a main effect on typing performance (Table 4). The main effect of participation in a typing class was not significant but the two predictors interacted (Table 4). As depicted in Figure 1C, best performance was achieved among those who had attended a typing class and at the same time viewed typing speed to be important in their everyday typing. This pattern was the same for performance on meaningful and nonsense material. Simple-slope β coefficients for participants who had attended a typing class were .73, t (56) = 4.41, $p < .01$, and .72, t (56) = 4.26, $p < .01$, for meaningful and nonsense material, respectively, and .15, t (56) = 0.98, *ns,* and .05, t (56) = 0.33, *ns,* for participants who had not attended a typing class.

Correction for Restriction of Range in SAT Scores

Because the SAT score is used as a criterion for university admission, there may be a restriction of range of SAT scores in the present sample of university students and, as a result, low correlations of this variable with the dependent variables. A correction for restriction of range (using the data by Dorans, 1999, and the formula by Thorndike, 1949) led to higher coefficients but did not change the correlational pattern with the dependent variables ($r_{corrected}$ = .19, *ns*, for nonsense material; $r_{corrected} = .46$, $p < .01$, for meaningful material).

Discussion

In the present study we applied deliberate practice theory, which was originally developed to explain expert performance, to intermediate-level performance on a widespread everyday task, namely typing., We examined the contributions of abilities, experience, and deliberate practice activities to performance in typing using a sample of experienced but non-professional typists. To test relations of abilities with typing performance, we included an indicator variable for general cognitive abilities (SAT scores), perceptual-speed (digit-symbol substitution), and motor abilities (tapping). To test relations of typing experience with performance, we included estimates of typists' typical amount of typing per week as well as their absolute amount of typing since starting to use the keyboard. Finally, as measures of deliberate practice activities, we assessed whether typists had attended a typing class in the past and to what extent they generally adopt the goal of typing fast when pursuing their everyday typing activities. We expected typists to perform who have both been exposed to systematic training (i.e., typing class) and who adopt the goal of high performance during every typing to demonstrate superior performance. To test these hypotheses, we examined performance on typing tasks that involved meaningful material (i.e., meaningful words and sentences) and nonsense material (i.e., isolated letters, syllables, and short words).

The indicator variables of perceptual speed (i.e., digit-symbol substitution; partial $\varepsilon^2 = .00$) and motor abilities (i.e., tapping speed; partial $\varepsilon^2 = .00$) did not predict typing performance. These findings may be interpreted as being not inconsistent with deliberate practice theory as they seem to suggest that these types of abilities do not contribute to typing performance in experienced typists. However, although the present sample size was adequate to detect a moderate effect of a predictor in a regression model with three predictors (cf. section on power analysis), it was too small to detect a small effect. Our failure to find significant predictions of typing performance by the digit-symbol substitution and tapping tests is consistent with other published studies (e.g., Kitson, 1927; Legrand-Lestremau et al., 2006), although some researchers have reported moderate correlations between these tests and typing performance (e.g., Flanagan et al., 1959; Salthouse, 1984).

As a proxy for general cognitive abilities, we included participants' SAT scores and found this variable to predict typing performance on meaningful ($\beta = .27$) but not on nonsense material ($\beta = .05$). Based on this finding, it may be speculated that verbal skills and abilities contributed to this advantage rather than general cognitive abilities per se. It seems plausible that verbal skills help to decode the text to be copy typed and/or to activate available motor programs for well-known words, resulting in a speed advantage for meaningful but not for nonsense material (cf. Rosenbaum, 1991; Salthouse, 1986). In line with this speculation, researchers have indicated that spelling ability is related to typing performance (Cohen & Wicklund, 1990; Limp, 1929). In the future, researchers should include measures of spelling and word knowledge for the particular words in the typed texts to examine this possibility rather than global measures such as total SAT score which combines math and verbal abilities. In addition, it may be informative to include experienced adults other than university students, because the SAT score is used as a criterion for university admission, with the result that there may be a restriction of range of SAT scores in the present sample and, as a consequence, low correlations of this variable with the dependent variables as well as with other variables included in the study (e.g., the somewhat unusual correlation of -.04 with the digit-symbol test). The particularities of the present sample may also have led to correlations among the ability variables that slightly differ from other studies (e.g., see Ackerman & Cianciolo, 2000), indicating that the present findings concerning the ability variables should be interpreted with caution. In fact, a correction for range restriction of SAT scores considerably increased the correlation between SAT scores and typing performance on meaningful material. On the other hand, the uncorrected correlation we found is comparable to estimates of the correlation between intelligence and typing performance in other studies that used samples with a wider range in intelligence. For example, in a study with several hundred high school students, Stedman (1929) found correlations that ranged from .22 to .33 (see also Flanagan et al., 1959, and West, 1969, for a review). In sum, the representative task of typing meaningful text material is significantly correlated with cognitive abilities. However, the question of the magnitude of the true population correlation as well as the question what general or specific mechanisms mediate this relationship cannot be answered based on the current data.

In line with traditional theories of skill acquisition (Anderson, 1982; Fitts & Posner, 1967), the absolute amount of typing that participants had accumulated since starting to use the keyboard had an effect on the typing of meaningful material. The more people typed, the faster they typed meaningful material ($\beta = .37$). In line with deliberate practice theory, the interaction of two variables, namely whether participants had attended a typing class in the past and the extent to which they reported to adopt the subjective goal of typing fast in everyday typing, contributed substantially to the prediction of typing performance, both on meaningful and nonsense material (partial $\varepsilon^2 = .12$). The highest performance was found among those participants who had attended a typing class and who found it personally important that they type fast when engaging in their everyday typing. This interaction effect suggests that attending a typing class may be a first step to deliberate practice, as participants have the opportunity to learn appropriate techniques and receive immediate feedback on their performance improvement. The best result, however, is achieved by those typists who, in addition to or after attending the typing class, push their typing speed during their everyday typing activities. Attending a typing class alone does not guarantee that a typist engages in deliberate practice, as a typing class appears to be useless (i.e., no significant main effect of participation in a typing class) if the participant lacks the motivation to improve, be it during the typing class or outside the class when engaging in everyday typing activities.

These findings are consistent with the claim that deliberate practice plays a role not only in fostering excellence in domains such as music, sports, and chess, but also for intermediate performance on a widespread everyday task. However, there seems to be one essential difference between the deliberate practice activities pursued by professional musicians, athletes, and chess masters on the one hand and the activities we described as deliberate practice in intermediate everyday typists on the other hand. As stated earlier, in classical domains of expertise, the definition of deliberate practice entails that practice activities are undertaken with the explicit goal of performance improvement. Only effortful and challenging practice activities during which individuals push themselves are considered to constitute deliberate practice, in contrast to more playful activities (e.g., playing the violin for fun, playing chess games). It could be argued that in the present sample of intermediate everyday typists, no such explicit goal of performance improvement was pursued (or at least we do not know the exact content of the goal) and that, therefore, the typing activities investigated do not constitute deliberate practice in the narrow sense of this concept. We base our analyses on whether participants usually pursue a speed goal as they type—irrespective of whether they do so in order to improve their typing skill, which would qualify as an explicit goal of performance improvement, or for any other reason that is unrelated to skill improvement (e.g., typing fast to get done with the homework sooner). It seems that for the present domain, it is sufficient for skill improvement to adopt a challenging performance goal during practice which is aimed at a specific standard of proficiency or outcome (Latham & Locke, 1991), even if this outcome does not explicitly entail skill improvement. Future research in other task domains may explore the feasibility of this extension of deliberate practice theory.

Another aspect of this study may be linked to existing expertise research. At first glance, our prediction (and finding) that deliberate practice variables do not interact with the type of material (i.e., meaningful vs. nonsense material) may seem at odds with the seminal work by de Groot (1978) who found level of chess expertise to be related to memory performance for valid (i.e., meaningful) chess positions but not for randomized (i.e., nonsense) positions. However, there are at least two aspects that differ between the domains of typing and chess. First, expecting an interaction between deliberate practice in typing and the text material (i.e., effects of deliberate practice on performance on meaningful but not on nonsense material) would particularly make sense if the basis of typing skill was the acquisition of psychomotor programs for complete—and meaningful—words, an assumption that is unlikely according to existing research on typing skill (Cooper, 1983; Gentner, 1983, 1988; Logan, 1982; Rosenbaum, 1991; Shaffer, 1976). Second, no effects of deliberate practice on performance on nonsense material would be expected if deliberate practice activities were solely directed at meaningful materials. However, many commercially used typing books and programs, which are also used in typing classes, include nonsense material in drills that aim to teach strict assignments of fingers to keys (e.g., Dobson, 2002; Erickson, 2004; cf. Yechiam et al., 2003).

Some cautionary remarks need to be made concerning the design of the present study. First, we have not directly measured typing experience or deliberate practice in typing. We had to rely on participants' retrospective reports about their typing experience and their deliberate attempts to improve their typing performance and we do not have any objective data available to verify this information (cf. Côté et al., 2005). Second, the present cross-sectional design does not allow any conclusions concerning causal directions. In future investigations of typing proficiency researchers should use longitudinal designs in which typing performance is measured several times over a longer period of time, preferably before onset of systematic training, and in which practice activities are assessed more directly and objectively. Third, all typing tasks used in this study had the form of transcription typing (i.e., copy typing text presented to participants on the computer screen). This procedure was necessary for standardization purposes (i.e., identical texts and typing duration for all participants). In everyday typing, when typists usually do not copy type but type a text they produce themselves, phases of typing and phases in which typists think about what to type will certainly alternate (Gould, 1981; Logan, 1983). We believe that this should not necessarily lower the ecological validity of this study, assuming that the processes underlying transcription typing with preview and production typing are not fundamentally different. In both cases, typists can prepare sequences of future keystrokes and move their fingers toward the corresponding keys ahead of time, albeit for different reasons: In transcription typing with preview because they can read the next letters to be typed and in production typing because they know the words and letters they are about to type (although the exact processes underlying production typing are not well understood; Cooper, 1983). Also, it is plausible to assume that a well developed typing skill can be useful for production typing, because attentional resources that are otherwise used for the act of typing can be freed up and devoted for idea generation (cf. Cooper, 1983; Gentner, 1988). Forth, from a practical perspective, it may be argued that nonsense material is irrelevant for real-world performance as it is not part of everyday typing material. From a theoretical perspective, however, the differential effects we found provides some indications with respect to the processes involved in the act of typing that are affected by abilities, typing experience, and deliberate practice. For example, the result that ability and experience variables were only related, if at all, to performance on meaningful material whereas deliberate practice showed the same pattern for both meaningful and nonsense material may indicate that abilities and experience did not affect typing skill per se but speeded up the process of decoding the source material (cf. Gentner, 1988)—a possibility that may be further explored in future research.

Finally, in the present study we raise some interesting questions concerning the distinction between mere engagement in an activity and deliberate practice. Early studies of highly skilled typists (Book, 1925a, 1925b; Dvorak, Merrick, Dealey, & Ford, 1936) suggest that an effective way to improve performance is to push one's typing speed beyond its comfortable level for short concentrated periods of 10-15 minutes per day and to then target difficulties that became evident during these periods (e.g., typing errors, slow transitions). Similar to other deliberate practice activities (Ericsson, 1996, 2006b), this type of activity cannot easily be conducted as part of regular typing because the induced increases in speed are likely to lead to increased error rates and, in turn, to time-consuming error correction procedures—at least this used to be the case in the days of early typewriters. Nowadays, where word-processing programs allow simple and fast error correction, it may be possible that everyday typists who are highly motivated to increase their typing speed can at least partially modify their engagement in typing into an opportunity for skill improvement. Another aspect of typing that may be important for improvement is the ample feedback this activity provides (i.e., typing errors can be detected and corrected easily by the typists themselves). In this regard, typing appears to share aspects with surgery where—in contrast to many other domains of medicine—experience is associated with improved performance (Ericsson, 2004), probably because feedback about success in surgery is immediately available to a surgeon.

In conclusion, in the present paper we sought to enhance our theoretical understanding of factors that contribute to skilled but non-expert performance on a task that is pursued by many people on an everyday basis, namely typing. We applied deliberate practice theory, which has been developed to explain expert performance, to intermediate-level typing performance. Our results suggest that the same mechanisms that underlie expert performance may be essential for performance on an intermediate level as well—at least for the domain under investigation. Future research may investigate to what other domains deliberate practice theory can be extended or, likewise, to what domains its applicability to intermediate-level performance is restricted. We believe that our research contributes to the present special issue as it shows how concepts from classical domains of expertise research may be fruitfully adopted to explain performance on a widespread and practically relevant everyday skill.

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Table 1

Descriptive Statistics and Intercorrelations of the Study Variables

Variable	*M*	*SD*	*Skew*	1	2	3	4	5	6	7	8
Ability variables											
1 SAT score	1129.47	141.14	0.59	–							
2 Tapping speed[a]	100.67	14.55	0.32	.22	–						
3 Digit-symbol substitution	87.33	12.49	-0.17	-.04	.02	–					
Amount of experience (text lines)											
4 Amount of typing typical week	427.15	460.25	1.63	.00	.03	.09	–				
5 Absolute amount of typing	18549.16	13740.44	1.16	.16	.12	.03	.21	–			
Deliberate practice											
6 Typing class[b]	0.07	1.01	-0.14	-.05	-.10	.07	-.01	-.02	–		
7 Subjective speed goal	5.98	1.87	0.01	-.02	-.05	.00	.14	.31*	.12	–	
Typing performance (net wpm)											
8 Nonsense material	23.77	8.13	0.32	.05	.05	.13	-.06	.14	.25	.38**	–
9 Meaningful material	33.02	9.69	0.28	.28*	.12	-.01	-.02	.35**	.23	.44**	.81**

Note. $N = 60$. Skew = Skewness. Net wpm = net words per minute.

[a] The tapping speed variable used in analyses is aggregated from *z*-standardized tapping tests (i.e., with a mean of zero); for illustrative purposes, the mean and standard deviation reported in this table pertain to aggregation of non-standardized tapping tests.

[b] Dichotomous variable; typing class attended = 1, no typing class attended = -1.

* $p < .05$. ** $p < .01$.

Table 2

Ability Variables and Typing Performance on Nonsense vs. Meaningful Material

Source	*df*	*F*	Partial ε^2	*MSE*
SAT score	1	1.75	.01	
Digit-symbol substitution	1	0.25	.00	
Tapping speed	1	0.17	.00	
Error	56			144.89
Material	1	187.27**	.77	
Material x SAT score	1	10.34**	.14	
Material x Digit symbol substitution	1	2.35	.02	
Material x tapping speed	1	0.16	.00	
Error	56			13.71

** $p < .01$.

Table 3

Typing Experience Variables and Typing Performance on Nonsense vs. Meaningful Material

Source	*df*	*F*	Partial ε^2	*MSE*
Amount of typing in a typical week	1	0.61	.01	
Absolute amount of typing	1	5.03*	.07	
Error	57			136.37
Material	1	180.49**	.76	
Material x Amount of typing in a typical week	1	0.03	.00	
Material x Absolute amount of typing	1	10.54**	.14	
Error	57			14.22

* $p < .05$. ** $p < .01$.

Table 4

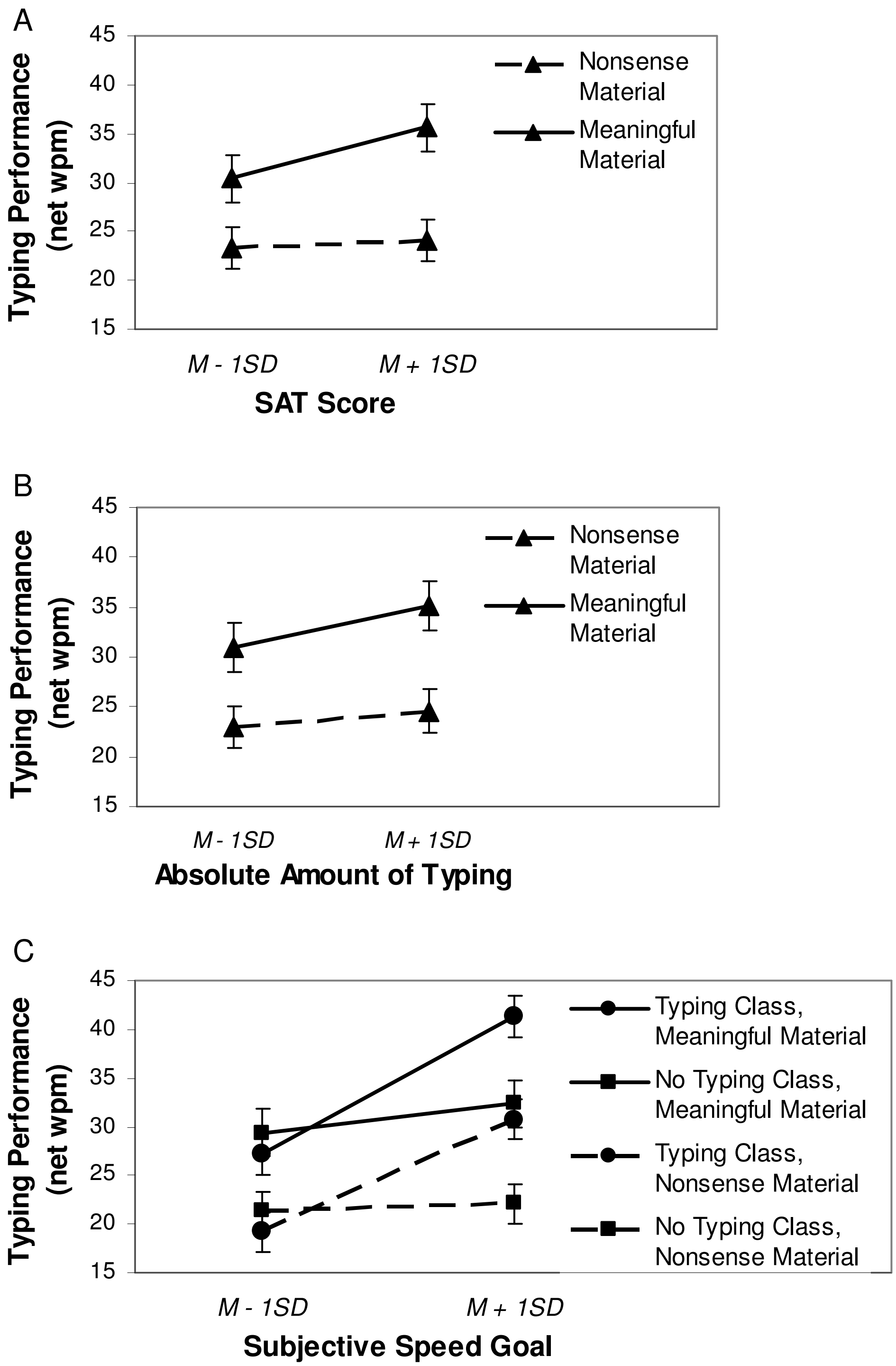
Deliberate Practice Variables and Typing Performance on Nonsense vs. Meaningful Material

Source	*df*	*F*	Partial ε^2	*MSE*
Typing class	1	3.22	.04	
Subjective speed goal	1	16.59**	.22	
Typing class x Subjective speed goal	1	8.44**	.12	
Error	56			101.63
Material	1	152.77**	.73	
Material x Typing class	1	0.01	.00	
Material x Subjective speed goal	1	2.35	.02	
Material x Typing class x Subjective speed goal	1	0.02	.00	
Error	56			16.51

** $p < .01$.

Figure caption

Figure 1. Interactions of SAT score (A) and of absolute amount of typing (B) with within-participant factor (typing performance on meaningful vs. nonsense material) as well as interaction of typing class attendance and subjective speed goal on typing performance on meaningful and nonsense material (C). Error bars represent 95% confidence intervals based on the point estimates and standard errors at predictor values of one standard deviation above and below the sample mean (for computational procedures see Aiken & West, 1991, p.132-133,).


A
Typing Performance (net wpm)
45
40
35
30
25
20
15
Nonsense Material
Meaningful Material
M - 1SD
M + 1SD
SAT Score
B
Typing Performance (net wpm)
45
40
35
30
25
20
15
Nonsense Material
Meaningful Material
M - 1SD
M + 1SD
Absolute Amount of Typing
C
Typing Performance (net wpm)
45
40
35
30
25
20
15
Typing Class, Meaningful Material
No Typing Class, Meaningful Material
Typing Class, Nonsense Material
No Typing Class, Nonsense Material
M - 1SD
M + 1SD
Subjective Speed Goal