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# An extension of the QWERTY effect: Not just the right hand, expertise and typeability predict valence ratings of words

Typing is a ubiquitous daily action for many individuals; yet, research on how these actions have changed our perception of language is limited. One such influence, deemed the QWERTY effect, is an increase in valence ratings for words typed more with the right hand on a traditional keyboard (Jasmin & Casasanto, 2012). Although this finding is intuitively appealing given both right-handed dominance and the smaller number of letters typed with the right hand, an extension and replication of the right-side advantage is warranted. The present paper re-examined the QWERTY effect expanding to other embodied cognition variables (Barsalou, 1999). First, we found that the right-side advantage is replicable to new valence stimuli. Further, when examining expertise, right-side advantage interacted with typing speed and typeability (i.e., alternating hand key presses or finger switches), portraying that both skill and procedural actions play a role in judgment of valence on words.

*Key words*: expertise, embodied cognition, valence, QWERTY effect

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While the mind was traditionally considered an abstract symbol processor (Newell & Simon, 1976), newer cognitive psychology theories focus on the interaction between the brain's sensorimotor systems and mental representations of events and objects (Barsalou, 1999; Zwaan, 1999). The interplay between these systems has been found in both neurological (Hauk et al., 2004; Lyons et al., 2010; Tettamanti et al., 2005) and behavioral research (Cartmill et al., 2012; Holt & Beilock, 2006; Zwaan & Taylor, 2006). Motor representations of tasks are activated even when an individual is not specifically asked to perform the task, and if the action is well-learned, the task is perceived as pleasant (Beilock & Holt, 2007; Ping et al., 2009; Yang et al., 2009). For example, Beilock and Holt (2007) asked novice and expert typists to pick which one of two letter dyads they preferred, which were either different hand combinations (*CJ*) or same finger combinations (*FV*). They found that novices had no preference in selection, while expert typists more reliably picked the combinations that were easier to type on opposite hands (*CJ*). Therefore, this study replicated the original typing effects found in van den Bergh et al. (1990). To expand on the van den Bergh et al. (1990) study, participants also made preference selections while repeating a key press combination to demonstrate that the preference effect was due to covert motor representation activation. When expert motor planning was distracted by remembering the pattern presented, no preference for letter dyads was found, indicating that the simultaneous activation of the motor representation was necessary to influence their likability ratings. Similar embodied findings have also been portrayed with emotionally charged sentences and facial movements (Havas et al., 2007), positive-negative actions, such as head nodding or arm movements (Glenberg et al., 2009; Ping et al., 2009), and perceptuomotor fluency (Oppenheimer, 2008; Yang et al., 2009).

## Body Specificity Hypothesis

Using an embodied framework, Casasanto (2009) has proposed that handedness dictates preference because our representations of actions are grounded in our physical interactions with the environment. In several studies, he showed that handedness influenced the preference for spatial presentation (i.e., left handed individuals associated "good" with left, while right handed individuals associated "good" with right), which, in turn, influenced judgments of happiness and intelligence and decision-making in hiring job candidates and shopping. In all these studies, participants reliably selected the hand-dominant side more often, which does not match cultural or neurolinguistic representations of positive is right and negative is left (Davidson, 1992). These findings imply that handedness is a motor expertise that causes ease of action on the dominant side to positively influence perceptions of items presented on that side. Further, Casasanto (2011) compiled a review of body-specific actions and their representations in the

brain using functional magnetic resonance imaging (fMRI) data. Handedness interacted with imagining actions, reading actions, and perceiving the meanings of action verbs such that the fMRI patterns were mirrored for left- and right-handed participants matching their dominant side.

## QWERTY Effect

These effects lead Jasmin and Casasanto (2012) to propose the idea that typing, an action that often replaces speaking, has the ability to create semantic changes in how words are perceived. The asymmetrical arrangement of letters on the QWERTY keyboard increases fluency of typing letters on the right side because there are fewer keys, and thus, less competition for fingers. That arrangement should then cause the letters on the right side to be perceived as more positive and letters on the left side to be perceived as more negative. Consequently, words that are composed of more letters from the right side of the keyboard (the right-side advantage; RSA) should be rated as more positive than those with more letters on the left. They found this preference for RSA in three languages (English, Spanish, and Dutch), and the effect was even stronger for words created after the invention of the QWERTY keyboard (i.e., lol), and it was evident in pseudowords such as plook. However, in contrast to the body specificity hypothesis, left- and right-handed participants showed the same trend in effects for positive is right words. The current study explored the interaction of the body specificity hypothesis with traditional embodied cognition theory. The body specificity hypothesis posits that individuals with different bodies should have different cognitive processes if cognition is influenced by the body structure (Casasanto, 2009). Therefore, participant bodily structure (handedness) should influence other cognitive judgments (ratings of pleasantness). We extended this work to other forms of embodied cognition by examining the interaction with expertise and fluency (Beilock & Holt, 2007). We tested the following hypotheses:

1) Expertise was measured through participant typing speed, and fluency or typeability was measured through finger and hand switches that would occur if the word was typed on a QWERTY keyboard (akin to Beilock and Holt [2007]'s different hand preferences). Given that typing involves the procedural action system, we expected to find that increased hand and finger switches (i.e., fluency, typeability) would be positively related to ratings of valence because words that are typed on alternating fingers and hands are easier to type, thus supporting embodied cognition theories. It was unclear if expertise would directly influence overall ratings, as we expected an interaction of the variables (described below). The RSA may still be present when accounting for these variables, as humans are primarily a right-side dominant species, and this result would support the body specificity hypothesis.

2) The interaction between RSA, fluency, and expertise was examined to determine if and how these different forms of embodiment may interact. This analysis allowed us to explore the nuance of skill and fluency on valence ratings and to determine the effects of the RSA at different levels of these variables.

# Methods

## Participants

Participants ($N = 606$) were recruited from the undergraduate human subject pool at a large Midwest university and received course credit for their time. A total of 72433 rows of data were collected from these participants. Five hundred and sixty-four participants had complete data (i.e., 120 rows, see below), 39 were missing one data point, and 3 were missing multiple data points. All possible data points were considered, and missing data points were classified as computer error (i.e., freezing during the experiment) or participant error (i.e., missed key press). Rating data were screened for multivariate outliers, and two participant's ratings were found to have extreme Mahalanobis distance scores (Tabachnick & Fidell, 2012) but were kept in the data set. 11.2% of the sample was left-handed, 0.2% was marked ambidextrous, and 0.3% was missing handedness information. The average typing speed was 47.89 words per minute ($SD = 13.31$), and the average percent accuracy rate for the typing test was 92.69 ($SD = 8.36$).

## Materials

The English ANEW (Bradley & Lang, 1999) norms were used to create the stimuli for this study in an effort to replicate Jasmin and Casasanto's (2012) experiments. A total of 2743 words were selected for this experiment. Pseudowords were selected from Appendix E of the supplementary materials presented from the QWERTY publication (Jasmin & Casasanto, 2012). These words were coded as described below for RSA, finger and hand switches, word length, and letter frequency. Average word length was 4.75 ($SD = 1.47$; range = 3 - 13) characters. All materials, data, and the Rmarkdown document that created this manuscript are available at our Open Science Framework (OSF) page: https://osf.io/zs2qj/. To replicate this manuscript specifically, please use the paper folder linked via our GitHub repository.

## Coding

Each of the words used in this study were coded for the control and experimental variables. The control variables included word length and average letter frequency. Average letter frequency was created by averaging the English letter frequency (Lewand, 2000) for each letter in each word. Words with high average letter frequencies contain more commonly used letters (*e*, *t*, *a*, *o*) while words

with lower frequencies use more of the less common letters (*z*, *q*, *x*, *j*). The experimental variables included RSA, number of hand switches, and number of finger switches. Typing manuals were consulted, and letters were coded as left (*q*, *w*, *e*, *r*, *t*, *a*, *s*, *d*, *f*, *g*, *z*, *x*, *c*, *v*, and *b*) or right-handed (y, *u*, *i*, *o*, *p*, *h*, *j*, *k*, *l*, *n*, and *m*). Left handed letters were coded with -1 and right handed letters with +1, which created summed scores indicating the overall right-side advantage for a word. Words were coded for the number of hand switches within a word using the left-right coding system described above. Finally, the number of finger switches were coded using traditional typing manuals for each finger. Finger switches were highly correlated with word length, $r = .89$, $p < .001$. Therefore, word length was excluded as a control variable due to a focus on typing skill in our hypotheses.

### Procedure

Upon consent to participate in the experiment, participants were given a typing test by using a free typing test website (TypingMaster, 2013). Each participant typed the text of Aesop's Fables for one minute before the website revealed their typing speed and accuracy rate, which was recorded by the experimenter. Participants typed in whatever style they felt most comfortable with (i.e., the experimenter did not direct them to type with one or two hands, they used their natural typing style). After this test, participants indicated their dominant writing hand. Participants were then given 120 of the possible stimuli to rate for pleasantness (60 real words, 60 pseudowords). This smaller number of stimuli was used to control participant fatigue/boredom. These stimuli were counterbalanced across participants, and the order of the stimuli was randomized. Participants were told to rate each word for how pleasant it seemed using a 9-point Likert-type scale (1 = *very unpleasant*, 4 = *neutral*, 9 = *very pleasant*). The self-assessment manikin from Jasmin and Casasanto (2012) was shown to participants at the top of the computer screen to indicate the points on the Likert scale. The words appeared in the middle of the screen in 18 point Arial font. Participants then typed the number of their rating on the computer keyboard. Once they rated all stimuli, participants were debriefed and allowed to leave.

## Results

### Data Analytic Plan

Because each participant constituted multiple data points within the dataset, a multilevel model was used to control for correlated error (Gelman, 2006). Pinheiro et al. (2017)'s *nlme* package in *R* was used to calculate these analyses. A maximum likelihood multilevel model was used to examine the hypotheses of interactions between typing speed, hand/finger switching, and RSA while adjusting for letter frequency when predicting item pleasantness ratings. Pseudowords and real words

were examined separately in two multilevel model analyses. Participants were included as a random intercept factor, as comparison to a nonrandom intercept was significant (see Table 1). Typing speed, finger/hand switches, and RSA were grand mean centered before the analyses to aid in interpretation of simple slope parameters (Cohen et al., 2003).

## Main Effects

After setting participants as a random intercept factor, letter frequency was used as an adjustor variable. As seen in the overall model in Table 1, this variable was not a significant predictor for pseudowords, $b = -0.006$, $t(35538) = -0.93$, $p = .351$, but was a significant predictor for real words, $b = 0.056$, $t(35684) = 6.10$, $p < .001$. All predictor statistics are provided in a .csv document on our OSF page for each step of the model. Next, the main effects of typing speed, hand switches, finger switches, and RSA were added to the models for pseudowords and real words. In both models, the addition of these variables overall was significant, $p < .001$. For pseudowords, typing speed was not a significant predictor for valence ratings, $b = 0.003$, $t(601) = 0.97$, $p = .332$. Similarly, typing speed was not a significant predictor for valence ratings on real words, $b = 0.000$, $t(604) = 0.04$, $p = .971$. In contrast, the measures of typeability in hand and finger switching were significant for both pseudowords and real words. For pseudowords, increased hand switching, $b = -0.026$, $t(35535) = -2.84$, $p = .004$, and increased finger switching, $b = -0.074$, $t(35535) = -5.85$, $p < .001$, decreased the overall valence ratings. However increased hand switching, $b = 0.061$, $t(35681) = 4.71$, $p < .001$, increased the valence ratings for real words, while increased finger switching, $b = -0.091$, $t(35681) = -7.82$, $p < .001$, decreased the overall valence ratings. Even adjusting for these typing style variables, the RSA effect was replicated for both pseudowords, $b = 0.050$, $t(35535) = 11.50$, $p < .001$, and real words, $b = 0.051$, $t(35681) = 8.35$, $p < .001$. In the

Table 1. *Multilevel Model Statistic Information for Pseudo and Real Words*

| Word Type | Model | *df* | AIC | BIC | $\chi^2$ | $\Delta\chi^2$ | *p* |
|---|---|---|---|---|---|---|---|
| Pseudo | Intercept only | 2 | 144345.73 | 144362.72 | −72170.87 | NA | NA |
| Pseudo | Random intercept | 3 | 134813.09 | 134838.57 | −67403.54 | 9534.65 | < .001 |
| Pseudo | Adjustor variable | 4 | 134814.22 | 134848.20 | −67403.11 | 0.87 | .351 |
| Pseudo | Main effects | 8 | 134577.92 | 134645.89 | −67280.96 | 244.29 | < .001 |
| Pseudo | Interactions | 19 | 134577.46 | 134738.87 | −67269.73 | 22.47 | .021 |
| Real | Intercept only | 2 | 168169.14 | 168186.14 | −84082.57 | NA | NA |
| Real | Random intercept | 3 | 166459.55 | 166485.05 | −83226.78 | 1711.59 | < .001 |
| Real | Adjustor variable | 4 | 166424.46 | 166458.46 | −83208.23 | 37.09 | < .001 |
| Real | Main effects | 8 | 166281.81 | 166349.81 | −83132.91 | 150.65 | < .001 |
| Real | Interactions | 19 | 166253.65 | 166415.14 | −83107.82 | 50.16 | < .001 |

next section, we explore the interactions of typeability and RSA to present a more nuanced view of the effect of typing on valence ratings.

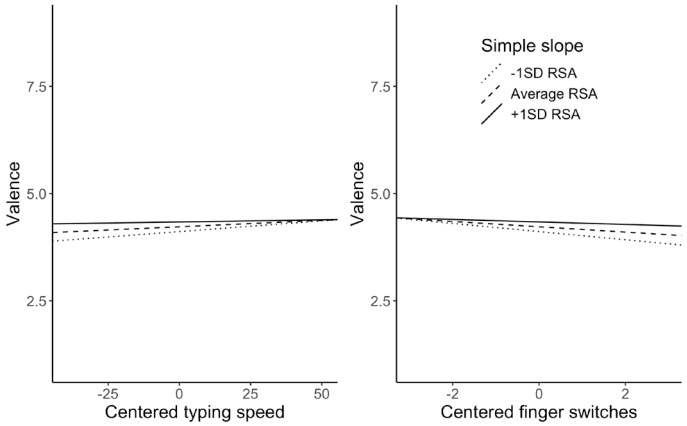
## Interactions

Next, the four-way interaction of typing speed, finger switching, hand switching, and RSA was entered into the equation, including all the smaller two- and three-way interactions. We focused on the most complex interaction found, breaking down interaction terms into simple slopes of low (−1*SD*), average, and high (+1*SD*) to explore each effect. For example, if the four-way interaction was significant, one variable would be broken into simple slopes, and the next most complex interactions would be examined. This procedure was iterated until the interactions were no longer significant or only main effects were examined. When multiple interactions were present, we chose a common variable to help break down the interactions with the least number of steps. Table 1 portrays that the addition of the interaction components was significant for both pseudoword, $p = .003$, and real word, $p < .001$, models.

### *Pseudoword Simple Slopes*

For pseudowords, finger switches × RSA, $b = 0.014$, $t(35524) = 2.66$, $p < .001$, and typing speed × RSA, $b = -0.001$, $t(35524) = -2.00$, $p = .045$ were the only significant interactions. Low and high simple slopes for RSA were created to examine the effects of typing speed and finger switches at these levels, and these interactions are displayed in Figure 1. For low RSA (words with more left handed letters), speed positively predicted valence, $b = 0.005$, $t(601) = 1.68$, $p = .094$, and finger switching negatively predicted valence, $b = -0.095$, $t(35524) = -5.68$, $p < .001$. For average RSA, speed no longer predicted valence, $b = 0.003$, $t(601) = 1.07$, $p = .285$, while finger switches still negatively predicted valence, albeit to a lesser extent than at low RSA, $b = -0.062$, $t(35524) = -4.76$, $p < .001$. Lastly, at high RSA (more right handed words), speed did not predict valence, $b = 0.001$, $t(601) = 0.32$, $p = .751$, and neither did finger switches, $b = -0.029$, $t(35524) = -1.51$, $p = .130$. In sum, this interaction indicated that expertise may be seen as positively influencing ratings for more left handed words, but it was not a predictor of words that were typed more with the right hand. When words were more left handed, there was a negative influence of finger switching, but transitioning to more right handed words, the number of switches did not influence valence ratings. These results seem to indicate that expertise and typeability were influential factors for left handed words, but the RSA washed out these effects when rating right handed pseudowords.

Figure 1. *Simple Slopes for Pseudowords Interaction Effects*



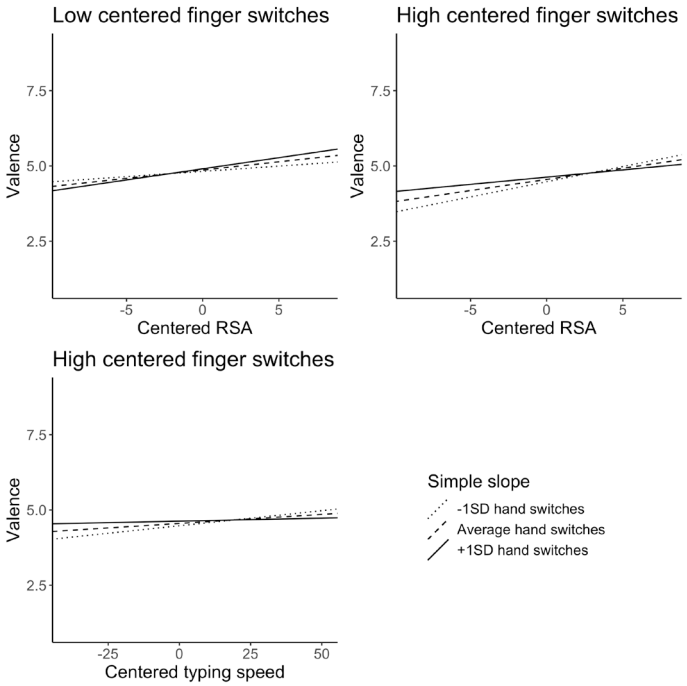

*Note.* The left plot indicates the speed interaction across simple slopes of RSA, while the right plot indicates the interaction of finger switches and RSA. Speed has positive effects when RSA is low (left handed words), while finger switches have negative effects when RSA is low.

### *Real Word Simple Slopes*

For real words, the three-way interactions of finger switch × hand switch × RSA, $b = -0.009$, $t(35670) = -5.00$, $p < .001$, and speed × finger switch × hand switch, $b = -0.001$, $t(35670) = -2.62$, $p = .009$, were the largest significant interaction predictors. Low and high simple slopes for finger switches were created to explore the three-way interaction. For lower finger switches, the hand switching × RSA interaction was significant, $b = 0.014$, $t(35670) = 1.70$, $p = .090$; however, the hand switches × speed interaction was not significant, $b = 0.000$, $t(35670) = 0.29$, $p = .772$. At average finger switching, the hand switches × RSA interaction was not significant, $b = -0.002$, $t(35670) = -0.38$, $p = .705$, and neither was the hand switches × speed interaction, $b = -0.001$, $t(35670) = -1.21$, $p = .228$. At a higher number of finger switches, the hand switches × RSA interaction was significant, $b = -0.018$, $t(35670) = -3.36$, $p = .001$, along with the hand switches × speed interaction, $b = -0.001$, $t(35670) = -2.62$, $p = .009$.

For significant two-way effects of hand switch × RSA and hand switch × speed, we then calculated the low and high simple slopes for hand switches (see Figure 2). Therefore, we explored the low and high finger switch effects that were significant with low and high hand switches for RSA and speed main effects. At low finger switches and low hand switches, RSA was a significant predictor of valence, $b = 0.035$, $t(35670) = 3.91$, $p < .001$. Speed was not examined because the two-way interaction was not significant. At low finger switches and average hand switches, RSA was a stronger predictor of valence, $b = 0.055$, $t(35670) = 3.86$, $p < .001$. Lastly, at low finger switches and high hand switches, RSA

Figure 2. *Simple Slopes for Real Word Interactions of Finger Switches by RSA by Hand Switches and Finger Switches by Speed by Hand Switches*




*Note.* The top left figure indicates the interaction for RSA and hand switches at low finger switches. The average level of finger switches did not show an interaction. The top right panel portrays the interaction of RSA and hand switches at high simple slopes for finger switches. The bottom left figure shows the interaction of typing speed and hand switches at high finger switches. Low and average finger switches did not show this interaction.

increased in strength, $b = 0.074$, $t(35670) = 3.07$, $p < .001$. Therefore, at low numbers of finger switches, as hand switching increased, the strength of the RSA positivity effect also increased. This result implies that as words require switching hands, words with more right handed letters during these switches are more likely to be rated positively in valence.

At a high number of finger switches, we found both speed and RSA interactions with hand switching (see Figure 2, top right and bottom left panels). When the number of hand switches for these words was low, RSA was a positive significant predictor, $b = 0.101$, $t(35670) = 7.96$, $p < .001$, along with speed, $b = 0.010$, $t(604) = 2.49$, $p = .013$. As hand switches increased, the effects of RSA and speed decreased. For high finger switches and average hand switches, RSA was significant, $b = 0.074$, $t(35670) = 8.75$, $p < .001$, and speed was also significant, $b = 0.006$, $t(604) = 1.98$, $p = .048$. With high finger and hand switches, RSA was significant but smaller than low and average, $b = 0.048$, $t(35670) = 4.71$, $p < .001$, and speed

was not a significant predictor, $b = 0.002$, $t(604) = 0.72$, $p = .473$. Therefore, at an elevated number of finger switches and a low number of hand switches, we found that RSA and speed were positive predictors of valence ratings. As hand switching and finger switching increased, the effects of expertise and RSA decreased. This result implies that the coordination of controlling for finger and hand switching decreases the positive valence effects of both RSA and expertise. All interaction statistics are included online in a .csv file on our OSF page.

## Other Considerations

### *Sensitivity*

While our study had many participants and data points, we calculated the minimum detectable effect for the highest reported interaction of hand switches × finger switches by RSA. We used the simr package (Green & MacLeod, 2016) to simulate multilevel models with the same statistical model as presented in the Results section with the same sample size and structure. For this interaction, we varied the parameter estimate to determine the b value that would replicate at $p < .05$ with 80% power in 1000 simulations. Results indicated that the interaction for pseudowords was minimally detectable at $b = 0.009$, and the interaction for real words was detectable at $b = -0.005$.

### *Other Variables*

Per reviewer request, we examined several variables in order to determine the stability of our results. One potential limitation noted in the Method section was the limited number of left-handed participants. However, our proportion of left-handed participants (11%) matched the approximate proportion expected from the general population (10%). We examined this variable as an adjustor variable in the same analyses, and the same direction and pattern of results were found.

Next, it was noted that the finger and hand switching variables are highly correlated with word length, which led us to exclude word length as an additional adjustor variable. Potentially, the results were simply an effect of word length. Therefore, we examined the same statistical model but first normed the switching and RSA variables by word length (i.e., variable divided by word length). Again, the same directions and patterns of results were found.

In our analyses, we used grand mean centering, a common approach for assisting in interpreting simple slope analysis parameters (Cohen et al., 2003). In grand mean centering, each data point is subtracted by the grand mean of the overall variable. While in a cluster mean centering approach, each data point is subtracted by the mean for that variable within an individual (i.e., Participant 1 data points minus Participant 1 mean for all data points). Cluster mean centering is a popular approach in longitudinal multilevel designs (Enders & Tofighi, 2007; Finkelstein-Fox et al., 2020). However, our results may be impacted

by the selection of items a participant rated, and we examined our statistical model using cluster mean centering, rather than grand mean centering, with the exception of typing speed (as this variable does not change by participant). Results showed the same pattern and direction as previously noted. This approach does markedly increase the standard error estimate of parameters, which means some effects were no longer significant. Given our focus was on items and simple slope analyses rather than individual differences, we included the grand mean centering approach in this study. Our supplemental file includes the results from these analyses and can be found on our OSF page.

Last, we examined our statistical model using a random slope of RSA in the main effects analysis. While the Akaike Information Criterion (AIC) values indicated an improvement to the overall model, given the extra parameter, the results did not change. Given we had no prediction for this parameter, and it is unclear how one would interpret a single random slope parameter within the complex interaction included in this analysis, we included this model in our supplementary analyses on our OSF page but did not include it in the results presented here.

## Discussion

These results replicated and extended the QWERTY effect to portray an interactive view of expertise, typeability, and RSA that lead to stronger valence ratings for words. The QWERTY keyboard layout has influenced perceptions of positivity, as hypothesized by the body specificity hypothesis, but the complexity of typing and action has additionally led to changing valence ratings for words. This influence was examined in our study by incorporating the work of Beilock and Holt (2007), wherein we measured typing speed as a measure of expertise, as well as embodied fluency or action through coding the way words would be typed with finger and hand switches.

### Replication of QWERTY and Extension to Embodied Variables

For pseudowords, we replicated the RSA effect, and additionally, showed that finger and hand switches predicted valence ratings. However, both switch variables were negative predictors, indicating that participants disliked words that required switching hands and fingers when adjusting for RSA, speed, and letter frequency. One interpretation of this finding may be that pseudowords are, by definition, not traditionally typed, which may have lead participants to rate words that required hand coordination, along with concentration on the physical letters, as less positive. If we imagine typing a captcha (i.e., a set of letters and/or numbers designed to eliminate spam responses), we may find that we would "peck" at the keyboard to hit the correct letter combination. Therefore, words that would require us to use more hands and fingers may be less desirable.

For real words, the RSA effect was replicated, and both switch variables

predicted valence ratings. In contrast to the pseudowords, we found that hand switching was a positive predictor of valence while finger switching was a negative predictor of valence. Hand switching coordination would be easier to manage than finger switches, especially as we consider the flexibility and movement range of the nonindex fingers. Therefore, it appeared that participants found words on different hands as more positive, replicating Beilock and Holt (2007), but when forced to coordinate switching finger movements, participants liked these words less. Many of the most frequent letters on the QWERTY keyboard are on the left side, which may frustrate a typist because of the need to coordinate finger press schemata that involve same finger muscle movements (Rumelhart & Norman, 1982). Consequently, the number of switches becomes increasingly important to help decrease interference from the need to continue to use the same hand. The ease of action by switching back and forth is then translated as positive feelings for those fluent actions (Oppenheimer, 2008). The complexity of this coordination's effect on valence was found in the multiway interactions unearthed in this study. Globally, typing speed was not a significant predictor for pseudo or real words.

### Interaction of Body and Embodied Variables

Pseudowords showed an interaction of typing speed × RSA and finger switching × RSA when predicting valence. In this interaction, we focused on RSA as the common variable between these interactions. When RSA was low, and thus, the words contained more left-handed letters, we found that speed positively influenced valence, while finger switches negatively predicted valence. For words typed completely on the right hand (high RSA), neither variable influenced valence. Therefore, it appears that when participants are required to use the left hand, and thus, lessen the influence of RSA, typeability and expertise play a role in the valence ratings of words. Both Beilock and Holt (2007) and van den Bergh et al. (1990) showed expert preferences for two and three letter combinations that were typed with different fingers. Our results could imply that our embodied actions influence preferences for procedures that are more likely in our environment. While our pseudowords were legal English phoneme combinations, they are extremely unlikely to have been previously practiced or encountered in daily tasks. Therefore, switching preference will not extend to pseudowords (unpracticed actions) because they are not fluent (Oppenheimer, 2008).

Further, three-way interactions of finger switches × hand switches × RSA and finger switches × hand switches × speed were found for real word valence ratings. At low finger switches (less than two finger switches), only the hand switches × RSA interaction was present. This interaction indicated that increasing hand switches also led to increasing effects of RSA on valence. Therefore, when finger switching competition was low, increased hand switching also lead to increased RSA effects. This effect indicates that right-handed words are still preferred, but additionally, words that are typed with opposite hands are rated as more positive.

At average finger switching, we found no two-way effects. However, at higher finger switching, we found both a speed and RSA interaction with hand switching. For RSA, increasing levels of hand switching led to lessening the impact of RSA. Therefore, when finger and hand switching needed to both be coordinated, RSA's impact on valence decreased but was still significant. For speed, we found that increasing levels of hand switching also led to lessened effects of expertise. This result runs counter to the idea that increased levels of hand and finger switching would require the most coordination, and thus, experts should be better at this task. This result instead implies that the effect of focusing on that coordination may dampen the effects of expertise on valence ratings.

## Conclusion and Further Directions

These embodied results mirror a clever set of studies by Holt and Beilock (2006) wherein they showed participants sentences that matched or did not match a set of pictures (i.e., the umbrella is in the air paired with a picture of an open umbrella). Given dual-coding theory (Paivio, 1991), it was not surprising that participants were faster to indicate picture-sentence matches than nonmatches (also see Stanfield & Zwaan, 2001; Zwaan et al., 2002). Further, they showed these results extended to an expertise match: Hockey and football players were much faster in sentence-picture combinations that matched within their sport than nonmatches, while novices showed no difference in speed for matches or nonmatches on sports questions. Even more compelling are results that these effects extend to fans of a sport and are consistent neurologically (i.e., motor cortex activation in experts; Beilock et al., 2008). These studies clearly reinforce the idea that expertise and fluency unconsciously affect our choices, even when it comes to the perceived pleasantness of words.

This extension of the QWERTY effect highlights the need to examine how skill and action can influence cognitive processes along with body structure. Our results support a complex interaction of both traditional embodied variables and the body specificity hypothesis rather than these effects operating individually. Additionally, typing style, while not recorded directly in this experiment, could potentially illuminate differences in ratings across left-handed and right-handed words. Hunt-and-peck typists are often slower than the strict typing manual typists, which may eliminate or change the effects of RSA and switches since typists may not follow left or right hand rules and just switch hands back and forth regardless of key position. The middle of a QWERTY layout also poses interesting problems, as many typists admit to "cheating" the middle letters, such as t, and y or not even knowing which finger should actually type the b key. Further work could also investigate these effects on other keyboard layouts, such as Dvorak, which was designed to predominately type by alternating hands to increase speed and efficiency (Noyes, 1983).

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## Research Ethics Statement

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