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Comparing Eyes-free Gestures to Gestures Produced in the Presence or Absence of Visual Feedback on Mobile Device

Yosra Rekik, Adnane Guettaf, Milad Jamalzadeh, and Laurent Grisoni

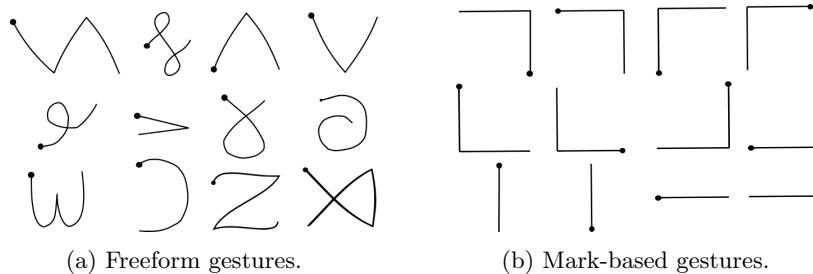
June 14, 2024

1 Abstract

In this paper, we compare eyes-free input gestures to gestures produced in the presence or the absence of a visual feedback for a single-handed mobile device interaction. We consider two gesture sets ((i) freeform gestures (operands, rationally invariant and mnemonic gestures) and (ii) mark-based gestures (on-axis rectilinear segments)) and two gesture beginnings (free: gesture can start from anywhere on the screen and bezel: gesture should start from one of the edge). Our findings indicate that gestures made in an eyes-free interaction were geometrically different from gestures generated in the presence or absence of visual feedback; they generated more directional movements around the y axis and had a lower recognition rate, which in itself was quite good (95.53%). Our findings also indicate that bezel gestures generated more phone movement and were less appreciated than those initialized freely. Freeform gestures were also preferred over mark ones. Based on those results, we propose five guidelines for eyes-free stroke gesture design, ergonomics, and recognizer development.

2 Introduction

Stroke-gesture input emerges as a promising avenue for eyes-free interaction with touchscreens, offering enhanced flexibility compared to conventional touches and swipes [Li(2010), Wobbrock et al.(2007)]. For instance, stroke-gesture enables efficient task execution [Li(2010), Wobbrock et al.(2007)] with minimal cognitive load [Appert and Zhai(2009)], making it particularly suitable for eyes-free interaction. The current practice of gesture interface design has studied stroke-gestures when being articulated in the presence or absence of visual feedback and has outlined several guidelines to assist practitioners in gesture recognition [Vatavu et al.(2012), Anthony and Wobbrock(2010), Anthony and Wobbrock(2012), Rekik et al.(2014a), Wobbrock et al.(2007), Rubine(1991)], user preferences [Anthony et al.(2013)], and geometric and kinematic features of articulated gestures [Kristensson and Zhai(2007),



(a) Freeform gestures.

(b) Mark-based gestures.

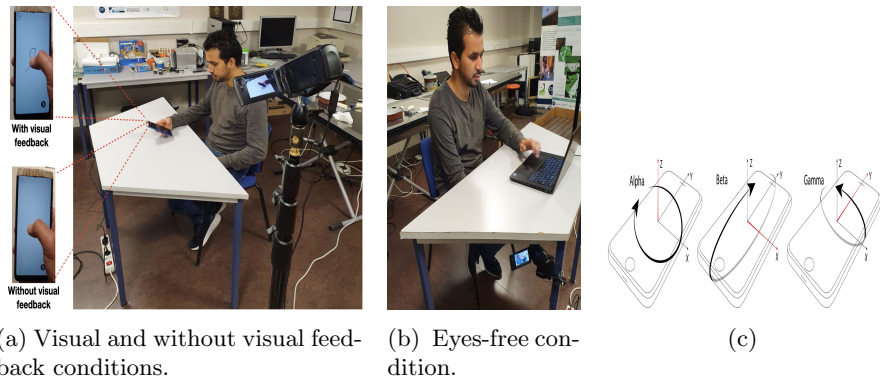
Figure 1: Gesture sets used during the experiment.

Anthony et al.(2013), Rekik et al.(2014b), Blagojevic et al.(2010), Vatavu et al.(2011)]. Recently, researchers have explored how engaging in a primary task influences the production of eyes-free gestures. For example, Bragdon et al [Bragdon et al.(2011)] examined empirically, the use of eyes-free stroke gestures when performing a primary task. Jamalzadeh et al. [Jamalzadeh et al.(2023b), Jamalzadeh et al.(2023a)] investigated the effect of user moving speeds and a saturation attention primary task on eyes-free gestures production.

However, to the best of our knowledge, no previous work has studied how eyes-free gestures differ from those produced when the user can see the phone? Additionally, as some existing techniques provide the users with a visual trace of the produced gesture (*e.g.*, drawing applications), and others do not (*e.g.*, navigation applications) [Anthony et al.(2013)], it is so important to examine how eyes-free gestures differ from those produced in the presence or the absence of a visual feedback when the user can see the mobile device. In this paper, we compared eyes-free gestures to gestures produced in the presence and absence of visual feedback for one-handed mobile device interaction. We then use our large body of results to compile a set of five guidelines for eyes-free stroke-gesture design, ergonomics, and recognizer development.

3 Experiment

The experiment used a $3 \times 2 \times 2$ within-subject design with these factors: visual *feedback*, gestures *set* and gesture *beginning*. Visual *feedback* covers three conditions: (1) *with visual* feedback, which means that participants can see the phone and have a visual trace of the articulated gesture; (2) *without visual* feedback, participants can see the phone but not the trace of the articulated gesture, and (3) an *eyes-free*, where participants cannot see the phone and no trace of the gesture input was shown. *Gesture set* and *gesture beginning* are similar to the work of Bragdon et al. [Bragdon et al.(2011)]. *Gesture set* covers the two conditions: *freeform* path gestures and *mark-based* gestures. Each set is composed of 12 unistroke gestures (see Figure 1). *Gesture beginning* covers two conditions: (1) *free*, where gesture can start from anywhere on the screen, and (2) *bezel*, where gesture should start from one of the four screen edges.



(a) Visual and without visual feedback conditions. (b) Eyes-free condition. (c) The phone directional movements.

3.1 Apparatus

We used a Huawei Y7 Pro running an Android operating system with an 8.1.0 version. The phone’s dimensions were $6.23'' \times 3.02'' \times 0.32''$. We developed our main application using JavaScript on React Native framework. The application was designed to support the three visual conditions and permit us to log all input event generated by our participants in an embedded database. For the *eyes-free* condition, in order to display the required gesture to draw, we implemented another application in JavaScript, which ran on a Dell laptop machine with a 13-inch LCD display screen with a desktop resolution of 1920×1080 pixels. Both applications communicated through the TCP protocol. The laptop application was only responsible for displaying gestures, and all the computing was still done on the phone side. We added a small piece of cardboard at the top of the screen to permit users to perform bezel gestures from the top of the screen without engaging the Android status bar. The cardboard dimensions were 1cm in height and 0.2cm in thickness, covering 0.35cm of the screen. Users’ hands were videotaped using two Sony HDR Camcorders as shown in Figures See Figures 2a-2b.

3.2 Task & Procedure

21 right-handed volunteers (8 women and 13 men) participated in the experiment. They were between 23 and 36 years old ($mean = 29.33, sd = 4.09$). They held the phone with their dominant hand and used the thumb of their dominant hand to draw gestures on the screen (single-handed grip), while sitting in front of a desk. For the *with/without visual feedback* conditions, participants interacted only with the phone. A preview of the gesture to be drawn was shown at the top left of the screen. For the *eyes-free* condition, participants dominant hand was put under the desk to ensure that the participants could not see the smartphone. A preview of the gesture to draw was shown on the laptop in front of them.

In the experiment phase, the three visual *feedback* were counterbalanced

among our 21 participants, and inside each *feedback*, the two gesture *beginnings* were counterbalanced. Inside each gesture *beginning*, the two gesture *sets* were also counterbalanced. For each gesture set, the twelve gesture types and their five repetitions were randomly presented, resulting in a total of 720 gestures drawn per participant. The experiment took one hour on average to complete.

4 Results

Our results include gesture features, gesture recognition, and mobile directional movements. All analyses used a multi-way ANOVA. Tukey tests were used post hoc when significant effects were found. Only significant effects and interactions are reported. We also analyzed qualitative observations.

4.1 Gesture Features

4.1.1 Gesture length

is the cumulative path distance from the first touch event registered for the gesture to the last. There were significant main effects of *feedback* ($F_{2,40} = 53.49$, $p < .0001$), *set* ($F_{1,20} = 360.15$, $p < .0001$) and *beginning* ($F_{1,20} = 18.00$, $p = .0004$) on *gesture length* with significant *set* × *beginning* ($F_{1,20} = 14.20$, $p = .0012$) interaction. Post hoc tests revealed significant differences among the three feedback conditions. Gestures made with visual feedback ($mean = 7.66cm$, $sd = 0.11$) were the shortest, followed by those made without visual feedback ($mean = 8.68cm$, $sd = 0.11$), and then eyes-free gestures ($mean = 10.21cm$, $sd = 0.12$) ($p < .05$). Furthermore, freeform gestures (bezel: $mean = 11.89cm$, $sd = .14cm$, free: $mean = 10.58cm$, $sd = .11cm$) were longer than mark-based gestures (bezel: $mean = 6.77cm$, $sd = .08cm$, free: $mean = 6.16cm$, $sd = .07cm$) ($p < .05$). Freeform condition produced also, significantly longer gestures when they started from the edge than when they started on a free space ($p < .05$).

4.1.2 Gesture height

is the height of the smallest bounding box that contains the gesture ($max_y - min_y$). There were significant main effects of *feedback* ($F_{2,40} = 38.10$, $p < .0001$), *set* ($F_{1,20} = 8.78$, $p = .0077$) and *beginning* ($F_{1,20} = 26.75$, $p < .0001$) on *gesture height*. Post hoc comparisons revealed that eyes-free gestures ($mean = 44.98cm$, $sd = .51cm$) are significantly higher than gestures produced in the absence of visual feedback ($mean = 3.87cm$, $sd = .04cm$) or in the presence of visual feedback ($mean = 3.41cm$, $sd = .04cm$) ($p < .05$). Freeform gestures ($mean = 4.03cm$, $sd = .03cm$) were significantly higher than mark-based gestures ($mean = 3.82cm$, $sd = .04cm$) ($p < .05$). Bezel gestures ($mean = 4.22cm$, $sd = .04cm$) were significantly higher than free gestures ($mean = 3.63cm$, $sd = .03cm$).

4.1.3 Gesture width

is the width of the smallest bounding box that contains the gesture ($max_{\mathbf{x}} - min_{\mathbf{x}}$). There were significant main effects of *feedback* ($F_{2,40} = 67.42, p < .0001$), *set* ($F_{1,20} = 205.08, p < .0001$) and *beginning* ($F_{1,20} = 30.61, p < .0001$) on *gesture width* with significant *feedback* \times *set* ($F_{2,40} = 13.37, p < .0001$), *set* \times *beginning* ($F_{1,20} = 89.36, p < .0001$) and *feedback* \times *set* \times *beginning* ($F_{2,40} = 6.63, p = .0032$) interactions. Post hoc comparison showed that mark-based gestures were significantly narrower than freeForm gestures for all feedback and beginning conditions ($p < .05$). For mark-based gestures, eyes-free gestures were significantly wider than both gestures produced in the presence and absence of visual feedback ($p < .05$). For freeForm gestures, for each feedback condition, bezel gestures were articulated with significantly larger width than those started on a free space ($p < .05$). When starting from the edge, in the presence of visual feedback, articulated gestures were significantly narrower than those in the absence of feedback or eyes-free ($p < .05$) with a significant difference between no-visual and eyes-free conditions ($p < .05$). For freeForm gestures, when starting on a free position, eyes-free gestures were produced with significantly larger width than gestures produced in the presence or absence of visual feedback ($p < .05$) with no significant differences between the presence and the absence of visual feedback.

4.1.4 Gesture area

is the surface area of the smallest bounding box containing the gesture (height \times width). There were significant main effects of *feedback* ($F_{2,40} = 52.90, p < .0001$), *set* ($F_{1,20} = 95.67, p < .0001$) and *beginning* ($F_{1,20} = 29.45, p < .0001$) on *gesture area* with significant *feedback* \times *set* ($F_{2,40} = 14.65, p < .0001$), *set* \times *beginning* ($F_{1,20} = 30.25, p < .0001$) and *feedback* \times *set* \times *gesture beginning* ($F_{2,40} = 9.53, p = .0004$) interactions. Post hoc comparison showed that mark gestures were articulated with significantly smaller area than freeform gestures ($p < .05$). For mark gestures, eyes-free gestures were articulated with significantly bigger area than gestures produced in the remainder feedback conditions ($p < .05$). For freeForm gestures, when staring the gesture from the edge, eyes-free gestures were articulated with significantly bigger area than gestures produced in the remainder feedback conditions with no visual being significantly bigger than those produced in the presence of visual feedback ($p < .05$). In contrast, when the beginning of the gesture is freely chosen, eyes-free gestures were produced with significantly bigger surface than gestures produced in the remainder feedback conditions ($p < .05$) with no significant difference between visual and no visual conditions.

4.1.5 Gesture duration

is the time elapsed while drawing the gesture, i.e., time of the last touch event registered for the gesture minus time of the first touch event. There were significant main effects of *feedback* ($F_{2,40} = 8.0, p = .0011$), *set* ($F_{1,20} = 71.95,$

$p < .0001$) and *gesture beginning* ($F_{1,20} = 5.31$, $p = .0319$) on *gesture duration* with significant *feedback* \times *set* ($F_{2,40} = 6.63$, $p = .0032$) and *set* \times *beginning* ($F_{1,20} = 4.91$, $p = .0383$) interactions. Post hoc comparison showed that for each feedback and beginning condition, freeForm gestures implies significantly more time to be drawn than mark gestures ($p < .05$). For freeForm gestures, the gesture duration in eyes-free condition ($mean = 1558ms$, $sd = 34ms$) was significantly bigger than no-visual feedback ($mean = 1317ms$, $sd = 27ms$) with no significant difference with the visual one ($mean = 1431ms$, $sd = 30ms$). For that gesture set, starting the gesture from the edge ($mean = 1500ms$, $sd = 25ms$) tended to take significantly more time than when being free ($mean = 1371ms$, $sd = 24ms$) ($p < .05$). Interestingly, for mark gestures there were no significant differences between the different feedback and beginning conditions ($p > .05$).

4.1.6 Gesture speed

is the average speed registered over all the touch events belonging to a gesture (length/duration). There were significant main effects of *feedback* ($F_{2,40} = 21$, $p < .0001$) and *set* ($F_{1,20} = 15.79$, $p = .0007$) on *gesture speed*. Post hoc comparison showed that gestures produced in the presence of visual feedback ($mean = 7.89cm/s$, $sd = .15$) were significantly slower than both gestures produced in the absence of visual feedback ($mean = 9.62cm/s$, $sd = .15$) or eyes-free ($mean = 9.58cm/s$, $sd = .14$) ($p < .05$). Freeform gestures ($mean = 9.03cm/s$, $sd = .08$) were significantly faster than mark gestures ($mean = 8.16cm/s$, $sd = .07$).

4.2 Gesture Recognition

We considered \$N-protractor [Anthony and Wobbrock(2012)] recognizer for both sets. However, as \$N generates for each multi-stroke gesture all unistroke permutations [Anthony and Wobbrock(2010)] in order to be independent from gesture order and direction and as we are concerned with stroke direction especially for mark-based gestures where two different gestures may share the same stroke shape but with different directions, *e.g.*, “up” and “down” gestures, we removed this feature. We then conducted user dependent training (which is appropriate for gesture recognition on personnel devices like mobile phones [Anthony and Wobbrock(2010), Anthony and Wobbrock(2012), Vatavu et al.(2012)]), in which recognition rates were computed individually for each participant with the same methodology as in [Wobbrock et al.(2007), Anthony and Wobbrock(2010), Anthony and Wobbrock(2012), Vatavu et al.(2012)]. Note that we conducted separate tests for each gesture set generated in different feedback and beginning conditions. We found significant main effects of *feedback* ($F_{2,40} = 7.03$, $p = .0024$) and *beginning* ($F_{1,20} = 14.69$, $p = .001$) on gesture recognition. Post hoc comparison showed that gestures produced eyes-free ($mean = 95.53\%$, $sd = .14\%$) were significantly less accurate than both gestures produced in the presence ($mean = 96.88\%$, $sd = .12\%$) or absence of visual feedback ($mean = 97.27\%$, $sd = .11\%$) ($p < .05$) with no significant difference between gestures produced in the presence and absence of visual feedback ($p > .05$). Free ges-

tures ($mean = 97.68\%$, $sd = .11\%$) were significantly more accurate than bezel gestures ($mean = 95.44\%$, $sd = .11\%$) ($p < .05$).

4.3 Mobile Directional Movement

We considered the same dependent variables as in [Eardley et al.(2017)] to characterize the phone’s movement (see Figure 2c). For each of the directional axes, using the built-in accelerometer and gyroscope we captured the total deviation made around this axis, calculated as the difference between the largest and the smallest value. Data were captured during gesture articulation.

4.3.1 Alpha deviation – deviation around z axis

There were significant main effects of *feedback* ($F_{2,40} = 3.31$, $p = .0464$), *set* ($F_{1,20} = 21.11$, $p = .0002$) and *beginning* ($F_{1,20} = 18.81$, $p = .0003$) on *alpha deviation* with significant *feedback* × *beginning* ($F_{2,40} = 5.24$, $p = .0094$) interaction. Post hoc comparisons showed that producing freeform gestures ($mean = 7.54^\circ$, $sd = .21$) caused more alpha deviation than when producing mark gestures ($mean = 7.54^\circ$, $sd = .21$) ($p < .05$). For eyes-free condition, starting the gesture from a free space ($mean = 6.04^\circ$, $sd = .17$) caused less alpha deviation than when starting the gesture from the edge ($mean = 9.70^\circ$, $sd = .65$). When starting the gesture on a free space, gestures produced eyes-free caused less alpha deviation than gestures produced in the absence of visual feedback ($mean = 8.78^\circ$, $sd = .19$) ($p < .05$).

4.3.2 Beta deviation – deviation around x axis

There were significant main effects of *feedback* ($F_{2,40} = 7.61$, $p = .0016$) and *beginning* ($F_{1,20} = 32.52$, $p < .0001$) on *beta deviation* with significant *feedback* × *beginning* ($F_{2,40} = 9.17$, $p = .0005$) interactions. Post hoc comparisons showed that for each feedback condition, gestures started from the edge caused more beta deviation than those which started on a free space (visual: (1) bezel: $mean = 7.15^\circ$, $sd = .21$; (2) free: $mean = 5.11^\circ$, $sd = .13$, no-visual: bezel: $mean = 8.58^\circ$, $sd = .23$; (2) free: $mean = 5.72^\circ$, $sd = .15$, eyes-free: bezel: $mean = 9.38^\circ$, $sd = .25$; (2) free: $mean = 5.67^\circ$, $sd = .14$) ($p < .05$). For bezel gestures, the presence of feedback caused less beta deviation than other conditions ($p < .05$).

4.3.3 Gamma deviation – deviation around y axis

There were significant main effects of *feedback* ($F_{2,40} = 23.21$, $p < .0001$), *set* ($F_{1,20} = 35.58$, $p < .0001$) and *beginning* ($F_{1,20} = 88.21$, $p < .0001$) on *gamma deviation*. Post hoc comparisons showed that, eyes-free gestures ($mean = 10.46^\circ$, $sd = .19$) produced significantly more gamma deviation than both gestures produced on the presence ($mean = 7.43^\circ$, $sd = .15$) or the absence ($mean = 8.22^\circ$, $sd = .16$) of visual feedback ($p < .05$). Freeform gestures ($mean = 9.67^\circ$, $sd = .14$) and bezel gestures ($mean = 10.81^\circ$, $sd = .16$) produced significantly more gamma deviation than mark gestures ($mean = 7.74^\circ$, $sd = .14$) and free gestures ($mean = 6.60^\circ$, $sd = .10$) ($p < .05$).

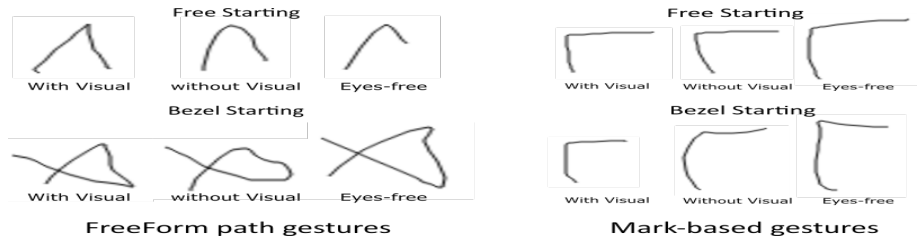


Figure 3: Examples of different gestures articulations produced in the three visual feedback conditions.

4.4 Observations

Participants felt confident in their gesture production in the three feedback conditions. However, they noticed deformations when provided with visual feedback, especially if they had initially performed without it. Figure 3 illustrates gesture articulations in eyes-free and visual feedback conditions. Six participants found drawing freeform gestures easier and more comfortable than mark-based gestures. They perceived mark-based gestures as initially simple, but found it challenging to draw them perfectly when provided with visual feedback. Additionally, they felt that freeform gestures appeared better executed than mark gestures in the presence of visual feedback. However, but interestingly, participants noted that visual feedback allowed for greater accuracy, enabling them to correct their actions. This observation aligns with Anthony et al.’s findings [Anthony et al.(2013)], indicating a preference for visual guidance in gesture drawing. Finally, most participants found bezel gestures to be more challenging and requiring more effort compared to free gestures. Some participants reported feeling “*more comfortable*” initiating bezel gestures from the right or left edges, finding them easier to reach. These findings are consistent with Karlson et al.’s research [Karlson et al.(2008)].

5 Discussion & Design Guidelines

Our findings indicate that eyes-free gestures were produced with significantly longer length and height, implied more phone movement around the y axis, and were faster than gestures produced in the presence or absence (except finger speed) of visual feedback. These results are consistent across different gesture sets and gesture beginnings. In contrast, gestures made in the presence of *visual feedback* were significantly shorter in length, height, and width (only when started from the edge) and slower than the ones made *without visual feedback* or in *eyes-free* conditions. In terms of gesture recognition, our findings indicate that eyes-free gestures were significantly less accurate than the two visual conditions, with no significant difference between gestures produced in the presence or absence of visual feedback.

When producing gestures in the *eyes-free* condition, bezel gestures were less accurate, and implied more mobile directional movements around all axes than free gestures. The same results were also observed for the two other visual

conditions, except for the directional movements around the z axis, and were consistent across the different set conditions. *Mark-based* gestures took considerably less space to be drawn in an *eyes-free* interaction than *freeForm* gestures: they were shorter in height and length. Consequently, they generated less directional movements to be performed than the *freeForm* set around both y and z axis. The same results were also observed for the two other visual conditions, and were consistent across the different set conditions.

Based on our findings, we outline five guidelines for designing one-handed eyes-free gesture articulation on mobile surfaces:

- (a) *Mark* gestures composed of at most two mark segments took considerably less space for the articulation than *freeForm* gestures. They are more adequate for small areas of articulations.
- (b) Prefer the use of gestures that can be initialized freely to bezel gestures. The gestures starting from one of the screen edges tended *to be less accurate*, and required additional hand rotations and more thumb movements.
- (c) If bezel gestures are required, opt for left and right edges that are easily accessible. This guideline is consistent with [Serrano et al.(2013)].
- (d) For Eyes-free and freeform gestures, which are longer, bigger and faster, employ recognizers that rely on geometric and kinematic gesture descriptors with caution, e.g. [Rubine(1991)] (p. 335).
- (e) Detect whether the gestures were bezel and make use of this knowledge to increase the tolerance of shape recognizers to vertical deformations.

6 Limitations & Next Steps

Like any study, ours has certain limitations. For example, the participants in our experiment were younger than the average population and all right-handed. Undoubtedly, older people, children, and left-handed people can exhibit different behaviours. Investigating these factors is important but falls outside the scope of the present work. Furthermore, our study instructed participants to use a single-handed grip while seated at a desk, which may limit the generalizability of our findings to interactions involving different hand grips [Eardley et al.(2017)] or body postures [Eardley et al.(2018)]. Additionally, we observed differences in gesture articulation between eyes-free gestures and those produced while looking at the touchscreen, impacting the recognition accuracy of the \$-family recognizer. Thus, investigating alternative recognizers such as HMM or DTW, or improving the \$-family recognizer to better handle eyes-free gestures, is justified.

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