Available online at www.sciencedirect.com

ScienceDirect

Procedia Manufacturing 3 (2015) 2395 – 2402

Procedia MANUFACTURING

6th International Conference on Applied Human Factors and Ergonomics (AHFE 2015) and the Affiliated Conferences, AHFE 2015

Effects of force feedback and distractor location on a CDTI target selection task

Kevin J. Monk[a,]*, Thomas Z. Strybel[b], Kim-Phuong L. Vu[b], Panadda Marayong[b], Vernol Battiste[a]

[a]NASA Ames Research Center, Moffett Field 94035, USA
[b]California State University, Long Beach, 1250 Bellflower Blvd, Long Beach 90840, USA

Abstract

New flight deck technologies need to be implemented in order to support the projected rises in traffic levels. Future cockpit displays of traffic information(CDTIs) shall accommodate the altered responsibilities of pilotsby facilitating more efficient routes and minimizing conflicts. However, the unstable nature of the cockpit may present challenges when precise inputs are required. The present study investigated the effects of force feedback and distractors on point-and-click movement times in a CDTI environment. Participants performed target selection tasks with multiple levels of force feedback and distractor location. Results implied that force feedback failed to benefit movement times relative to the standard computer mouse. However, substantial interactions between distractor effects, force levels, and other target characteristics are explored.

Peer-review under responsibility of AHFE Conference

*Keywords:*Force feedback; Distractor; Haptic; CDTI; Movement task

1. Introduction

The expected rise in air traffic volume over the next five years will likely escalate demands on pilots and air traffic controllers (ATCs) operating in the United States National Airspace System (NAS) [1]. Traffic density as little as 50% greater than current day levels has been found to negatively impact ATC performance [2]. The structure

* Corresponding author. Tel.: +1-650-604-1910.
E-mail address: kevin.j.monk@nasa.gov

Peer-review under responsibility of AHFE Conference
doi:10.1016/j.promfg.2015.07.388

of the current navigation system must be altered in order to address these increased demands [3,4]. The Next Generation Air Transportation System (NextGen) seeks to maintain air safety while cutting travel times and fuel costs. A concept within NextGen called Trajectory Based Operations (TBO) shall establish new flight operations and avionic technologies that afford pilots the flexibility to make more efficient flight plan deviations in mid-flight. The continuous transition to digital pilot-controller communication will also require more automated technologies in the flight deck, as pilots will be more accountable for the management of their route. The Cockpit Display of Traffic Information (CDTI), for example, would support efficient spacing practices with automatedconflict detection and route modification capabilities[5]. The Cockpit Situation Display developed in NASA Ames Research Center's Flight Deck Display Research Labororatory also increases pilot awareness by displaying pertinent information such as surrounding traffic and terrain on a three-dimensional graphical interface[6]. However,the limited workspace and unstable nature of the cockpit may obstacles for quick and precise inputs from pilots. An input device that can handle factors like turbulence and vibration needs to be implemented.

New cockpit interfaces developed to support common CDTI tasks (such as point-and-click) would preferably incorporate multi-sensory feedback to replicate real-world interaction [7]. Multiple Fitts's Law studies have explored the speed-accuracy tradeoffs of point-and-click tasks when using input devices enhanced with force feedback[8].The optimized initial impulse model states that point-and-click tasks likely involves an initial approach that either over or undershoots the target, followed by a corrective movement in the selection stage [9]. Force feedback supports difficult target selection tasks that require high precision by either guiding the motor movement toward a target region with attractive (gravitational) force fields or repelling a selection tool's cursor away from an undesirable region with resistant **(**spring) force [10,11]. Specifically, the attractive force aids the approach stage by pulling the cursor to the target's center upon reaching the boundary. Spring force aids the selection stage that involves stopping the cursor inside of the target and successfully clicking it.Therefore, an operator can make a speedy approach to a target and rely on force feedback to lock the cursor within the boundary without overshooting the target. Attractive basins have been found to reduce subjective workload, errors, and movement times with inefficient input devices [12,13,14,15,16]. For motion-impaired users, gravity wells have also improved point-and-click selection times by 50% and allowed them to match and exceed performance of able-bodied users [17].

Force feedback findings have varied depending on the input device. Force feedback-enhanced mice have improved target selection times and decreased errors compared to a standard computer mouse in graphical user interface (GUI) tasks with gravity wells present [18,19]. However, the force feedback mouse failed to improve selection times when equipped with spring force [20]. Many studies assessing force feedback have primarily used a computer mouse as the input device, but a mouse would not be applicable for use in a cockpit environment. While the Novint Falcon (a 3D gaming device with the capability of programming multiple force levels; [21]) is not intended for current-day commercial cockpits either, it has been considered a suitable device for simulated CDTI tasks. Past studies examining CDTI task performance with the computer mouse compared to the Novint Falcon (with and without force) indicated that gravitational force decreases overall movement times regardless of force level; furthermore, attractive force yields faster movements along the diagonal axes, which require more finely controlled motor movements than vertical directions [16,22]. Spring force feedback that did not take effect until inside the target had a minimal effect on movement times with the Novint Falcon [16].Resistant force has also received lower acceptability and higher workload ratings from users, thus suggesting that attractive force is ideal [12].

Although the aforementioned research notes the benefits of force feedback in routine and difficult tasks, there was only one target of interest to be selected on the displays. It is unrealistic to have only one force feedback-enhanced target on a CDTI, as navigational aids and surrounding traffic would surround ownship in a high density airspace. Additional cognitive processes are necessary to filter distractors when present, especially for unfamiliar visual tasks and motor movements [23,24].The inclusion of distractors has influenced movement path trajectory and increased movement times by nearly 24% when applying the same amount of spring force feedback as the target [20,25].While attractive force has improved movement times by 22% when applied to multiple potential targets compared to conditions without force feedback, it increased frustration and the physical effort required to push through undesired targets that attracted the cursor [12]. Force feedback has been shown to interfere with the intended movement of users, but the lack of variance in difficulty, force levels, target distance and size in previous literature needs to be addressed to make more definitive conclusions. The design of future 3-D traffic displays shall aim to maintain the benefits of force feedback in the presence of distractors. The present study examines operator performance on a target selection task with varying levels of force feedback applied to targets of different sizes and distances in a CDTI environment.

2. Method

2.1. Participants

Twelve right-handed participants (8 male, 4 female; M_{age} = 26.08 years old)from the San Jose State University Research Foundation were recruited for this study. All participants reported either normal or corrected-to-normal vision.

2.2. Apparatus

The present experiment was conducted in Flight Deck Display Research Lab located at NASA Ames Research Center. The two input devices utilized in the study were the Novint Falcon and a Logitech laser mouse. The Novint Falcon input device was equipped to sense position and apply force feedback in two dimensions of 4” x 4”, which enabled participants to make movements parallel to the ground. Participants used the button of their choice on the Falcon’s interchangeable hand grip to select a target during each trial. The Novint Falcon was positioned to the right of the participant on a stand that was elevated to a height that minimized wrist, arm, and shoulder strain. The center of the computer monitor was positioned at eye level and approximately 24 inches from each participant. The CDTI test bed displayed the green start icons, red target icons, and white distractor icons on the screen.

The standard computer mouse did not have force feedback enabled. Varying levels of force were activated on the Novint Falcon in the force feedback conditions. An attractive force was applied to the center of target and distractor icons using a modified version of Newton’s gravitational law equation [26](see Equation 1), where F is the gravitational force generated, K is the gain constant, d is the distance from the icon’s center,$\hat{d}$ is the distance vector unit that determined the amount of force applied along the x and y axes, and r is the icon’s radius.Gravitational force (expressed in Newtons/Pixel^2) steered the cursor toward the icon’s center upon reaching the boundary of the icon ($||d|| > r$), and the strength of the force increased as the cursor approached the center.

$$F = \left(\frac{K}{||d||^2}\right) \hat{d}\ [when\ ||d|| > r] \tag{1}$$

A spring force model was also applied once the cursor was inside the icon (d £ r) [16]. The spring force applied resistance to movements that traveled away from the center icon, with the resistance level increasing as the cursor moved away from the icon’s center. Spring force has been found to reduce target selection times, especially for smaller targets [16].This additional force model was added to provide stability to the selection of intended targets by allowing the participant to “lock in” on a target once inside its boundary. The spring force gain level (0.2 Newtons-Pixel), an ideal value based on previous findings [16] and informal pilot testing, was held constant throughout the study.

2.3. Design

The standard computer mouse served as the input device for the baseline no-force condition since movement timesfor selection tasks using the Novint Falcon without force have been found to increase up to 47% compared to Falcon tasks with force enabled [16,22]. The four experimental blocks in the mouse condition had a 3 (Movement Direction) x 2 (Distractor Location) x 2 (Target Distance) x (Target/Distractor Size) repeated measures design. For experimental blocks using the force feedback-enabled Novint Falcon, the study was a 2 (Gravitational Force Level) x 3 (Movement Direction) x 2 (Distractor Location) x 2 (Target Distance) x (Target/Distractor Size) within-subjects design (see Table 1). There were ten experimental blocks with the Novint Falcon, five with the lower level of gravitational force (100Newtons/Pixel^2) and five with the higher level of gravitational force (300 Newtons/Pixel^2). Although the Novint Falcon was capable of applying higher force than the two gain levels used in the present study, values higher than 300 Newtons/Pixel^2 have not been found to provide any additional benefit to selection tasks without distractors [16]. Since the present study applied force feedback to surrounding distractors in addition to the target, the force values used were considered ideal for maintaining adequate control of the device. The remaining variables were randomized within each experimental block. The dependent variable was overall movement time (OMT), which was the total elapsed time between the selection of the start icon and the target selection.

The red target circle was surrounded by white distractors of the same size (either ‘Small’ or ‘Large’) in each experimental trial. Distractors located in the direct path from the start icon to the target icon were considered ‘In Line’ distractors, while distractors that did not impede the direct path to the target were considered ‘Out of Line’. In trials with Out of Line distractors, a direct movement toward the target in a straight line would have led the cursor to the target icon without getting attracted to distractors. As shown in Fig. 1**,** In Line distractors had a square-shaped layout around diagonal targets, and a square-shaped layout around vertical targets. Conversely, Out of Line distractors had a diamond-shaped layout around diagonal targets and squared-shaped layout around vertical targets. While the distance between the start and target icon varied within trials (either ‘Near’ or ‘Far’), the surrounding distractors’ distances from the target were held constant across all trials. Movement direction was based on the target’s angle relative to the start icon, which was always positioned at the bottom-center of the display (corresponding to 180° or 6 o’clock).A target presented directly above the start icon at 360° (i.e., 12 o’clock) was considered a ‘Vertical’ target. Targets that were presented at 315° and 45° were considered ‘Diagonal-left’ and ‘Diagonal-right’ targets, respectively.

Table 1.Independent Variables

Independent Variable	Levels
Target & Distractor Size	Small: 0.5cm
	Large: 0.75cm
Target Distance	Near: 6.5cm
	Far: 10.5cm
Distractor Location	'In Line',
	'Out of Line'
Movement Direction	315° (Diagonal-Left),
	360° (Vertical),
	45° (Diagonal-Right)
Gravitational Force Level	Baseline/Mouse (No Force),
	100 Newtons/Pixel^2 (Low Force),
	300 Newtons/Pixel^2 (High Force)

2.4. Procedure

The experimental session began with participants filling out informed consent, screening, and demographics forms. Once it was confirmed they were eligible, they were briefed on the study. Participants then completed practice sessions with each input device to familiarize them with the task. Each target selection trial displayed a green start icon along with a red target icon surrounded by white distractors on the CDTI. Once the start icon was clicked, they used either the mouse or Novint Falcon to move the cursor toward the target icon. The green circle turned white after being selected to confirm the start of the trial. The movement task was to be completed as quickly and accurately as possible. Participants were free to choose between avoiding the distractors and moving the cursor through distractors on their path toward the target. The trial ended once the target icon was clicked. Participants were able to complete blocks at their own pace and rest when needed, as each trial started after selection of the start icon.There were 120 target selection trials within each experimental block. There were 24 possible combinations of target size, distance, distractor location, and movement direction total, and participants were presented with each unique combination of variables five times per trial. Participants completed a total of 1,200 trials with force feedback and 1,680 trials overall over the course of the experiment.

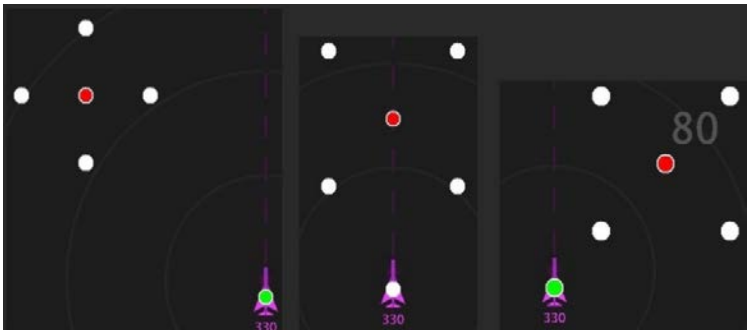

Fig. 1. Examples of icon positions on display, from left to right. Far/Small Diagonal-Left target with Out of Line distractors; Near/Small Vertical target with Out of Line distractors (after start icon has been clicked); Near/Large Diagonal-Right target with In Line distractors. [27]

3. Results

Operator performance with the computer mouse was examined with a 3 (Movement Direction) x 2 (Distractor Location) x 2 (Distance) x 2 (Size) repeated measures ANOVA. There was a main effect of target size on overall movement time, with large targets (M = 963.30ms, SEM = 20.04ms) being selected faster than small targets (M = 1045.59ms, SEM = 23.00ms), $F(1, 11) = 47.62$, $p < .001$. Movement direction also significantly affected movement times, $F(2, 22) = 4.31$, $p < .05$. Specifically, participants selected vertical targets in the 0° direction (M = 978.31ms, SEM = 20.39ms) faster than targets in the diagonal-right direction (45°, M = 1010.91ms, SEM = 22.34ms). Analyses also revealed a main effect of target distance, where targets near to the start point (M = 957.26ms, SEM = 22.51ms) were selected faster than farther targets (M = 1051.62ms, SEM = 19.78ms), $F(1, 11) = 115.73$, $p < .001$. No significant interactions were found between variables, p's > .05. Movement times in the baseline mouse condition (no force; M = 1004.44ms, SEM = 20.73ms) were consistently quicker than those in the 100 Newtons/Pixel^2 (low force; M = 1305.23ms, SEM = 62.69ms) and 300 Newtons/Pixel^2 (high force; M = 1234.69ms, SEM= 55.45ms) force conditions when comparing operator performance between input devices, $F(2, 22) = 20.95$, $p < .001$.

For results obtained with the Novint Falcon, a 2 (Gravitational Force Level) x 3 (Movement Direction) x 2 (Distractor Location) x 2 (Distance) x 2 (Size) repeated measures ANOVA was conducted on overall movement time. Force feedback analyses revealed a significant main effect of target distance on overall movement time, with targets near to the start point (M = 1206.27ms, SEM = 52.29ms) being selected faster than targets far from the start point (M = 1333.65ms, SEM = 57.19ms), $F(1, 11) = 415.81$, $p < .001$. There was also a significant main effect of movement direction, where participants selected targets in the diagonal-left direction (315°; M = 1234.45ms, SEM = 52.06ms) faster than targets in the diagonal-right direction (45°; M = 1291.42ms, SEM = 54.96ms), $F(2, 22) = 6.09$, $p < .01$. Target size also significantly affected movement times, with small targets (M = 1257.98ms, SEM = 55.09ms) having shorter OMTs than large targets (M = 1281.94ms, SEM = 54.82ms), $F(1, 11) = 5.26$, $p < .05$. There was no significant difference in movement time between vertical target selection (0°) and movements toward either diagonal direction.

No significant main effects of gravitational force level or distractor location were found, p's > .05. However, a significant five-way interaction was observed between gravitational force level, direction, distance, distractor location and size, $F(2, 22) = 3.73$, $p < .05$. Repeated measures ANOVAs were conducted with each variable held constant to determine the nature of the interaction. Analyses revealed a significant three-way interaction between target distance, direction, and distractor location when controlling for large targets with the 300 Newtons/Pixel^2 force level, $F(2,22) = 4.11$, $p < .05$. The OMTs of large target selection with high force were affected by distractor location when in the diagonal-right direction, while target distance impacted their OMTs in the vertical direction. Movement times for large diagonal-right targets with high force were quicker when surrounded by In Line distractors (M= 1160.80ms, SEM = 57.46ms) compared to Out of Line distractors (M = 1408.09ms, SEM = 68.46ms). Conversely, In Line distractors (M = 1344.05ms, SEM = 86.53ms) increased OMTs for large vertical targets with high force compared to Out of Line distractors (M = 968.59ms, SEM = 43.60ms), but only when near the start icon (see Fig. 2).

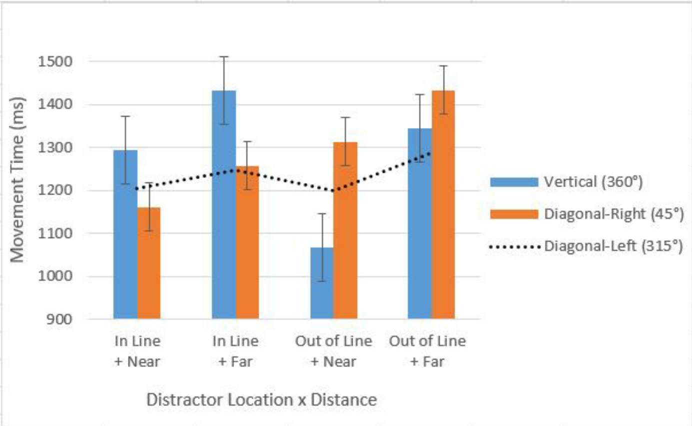

Fig. 2. Overall movement times for targets by direction, distractor location and distance. Significant interaction for large targets with high force, $p < .05$.

4. Discussion

Previous findingshave highlighted the performance benefits of force feedback on point-and-click tasks in various display frameworks. Gravitational force feedback quickens movement times by supporting the approach to the target, while spring force stabilizes the selection stage of the task by shortening time spent inside of the target [11]. However, distractor targets have been found to be increase cognitive workload, and may diminish the advantages that force feedback provides to a selection task [12,23]. The consequences of distractor effects must be addressed if force feedback is to be considered for future cockpit technologies, as multiple targets would appear on a traffic display in a high density airspace. The present study sought to further preceding research by examining how the presence and location of distractors armed with an equal level of force feedback impacted operator performance on an aimed movement task in a CDTI environment.

The benefits of force feedback discovered in previous literature were not reproduced in the presence of distractor targets. Gravitational force levels up to 300 Newtons/Pixel^{2}failed to improve operator performance relative to the computer mouse in any instance.In fact, movement times were 21% longer when using the force-enabled Falcon. Distractor targets likely complicated the selection task when using the Falcon since they were enhanced with force feedback levels equal to that of the target.Also contrary to past findings without distractors, there was no significantmovement time difference found between the two gravitational force levels. Nonetheless, the increase from 100 Newtons/Pixel^2 to 300 Newtons/Pixel^{2}gravitational force resulted in a 5% improvement in movement times. Though gravitational force has previously maintained performance benefits with distractors present, the constant level of spring force applied to the target and surrounding distractors in the current study (0.2 Newtons-Pixel) may have further disrupted the selection task [12].Distractors have been found to counteract the benefits of spring force feedback, which resists movement away from the target once within the boundary [20].

The effects of distractor location and force feedback in the current study were qualified by their interactions with the other target variables. The location of the distractors affected movement times differently depending on the movement direction and target distance. In Line distractors increased movement times for vertical targets directly above the start icon, but only when near the start point. The distractor location no longer impacted vertical movement times when the target was presented at a farther distance.Close vertical targets among Out of Line distractors had the fastest movement times of any unique combination of variables in the present study. This combination of variables likely presented the most direct path to the target with the least potential for encounters with distractors. Thus, it is probable that this was the most favorable situation for experiencing the benefits of force feedback. Once the targets were farther away, there was more room for error on the path to the target. The mere presence of distractors have been found to affect movement endpoints [25], so participants may not have been able to remain on a direct path to a vertical target as easily with the added distance.

Conversely, In Line distractors reduced movement times for diagonal -right targets in the 45 direction regardless of distance. Participants may have had more difficulty maintaining a controlled, aimed movement along a direct path when selecting targets to the right. It is possible that this led to inadvertent penetrations of Out of Line distractors. Movement times for diagonal-left targets were not impacted by distractors or any other variables, and remained consistent across all analyses with force feedback. Movements toward the left with the Falcon may have simply been more comfortable and controlled for the right-handed participants.It is not concluded that the location or presence of distractors had the biggest influence on the above findings in particular, as vertical movement directions have consistently produced the slowest movement times in Falcon feedback tasks overall regardless of distractor presence in past studies [16,22].Gravity wells have been found to improve movement times in diagonal directions because they require more precise motor movements compared to the vertical direction. There is also a possibility that these findings are specific to the Novint Falcon device itself, especially with the limited training and experience of the participants.

Nonetheless,the interactive effects of distractor location, target distance and direction on Falcon movement times were most prevalent in trials containing larger targets with the higher force level of 300 Newtons/Pixel^2.Large target size negatively impacted operator performance when using the Falcon. This finding conflicted with the movement time improvements that large target sizepresented in the computer mouse condition. However, the force models have been shown to benefit selection of small targets with or without distractors, as they require the most finely controlled movement in the selection stage [22].Despite the common benefits this model provides for target selection, it presented a disadvantage when a distractor target was penetrated. Larger distractor targets were likely more difficult to avoid, and thus, may have hindered operator performancewhen they were encountered with force feedback enabled. This hindrance would have been more apparent with a higher level of force, and this is supported by the fact that the effects of target size and force feedback were qualified by their interactions with the other target variables. The trends remained intact for trials with small target size and the 100 Newtons/Pixel^{2}force level, albeit weaker in magnitude. The nature of the distractor effects in relation to movement direction and target distance suggest a direct association with the likelihood of participants penetrating the force-enhanced distractors, while the strength of the relationships (positive or negative) increased when targets were larger with the higher level of force. Cursor path trajectories would need to be collected and analyzed in order to determine whether participants were successfully avoiding the distractors or penetrating through them on the way to the target, as they were not explicitly instructed on how to approach the target.

Results suggest that aimed movement tasks in a CDTI environment become more problematic when there are multiple targets enhanced with force feedback. However, the findings may not necessarily apply to other types of input devices that are more suitable for use in a commercial cockpit. Future research should further these claims with different input devices (perhaps with highly trained operators), multiple combinations of force feedback, variations in spatial layout and quantity of distractors, objective measures of musculoskeletal load, and more complex movement tasks, i.e. click-and-drag. Future analyses of path trajectories would also provide more insight on which approach strategies are more common and efficient in the presence of distractor targets. Extensions of this research shall inform more concrete conclusions with regard to the feasibility of haptic feedback technologies in dynamic display environments.

Acknowledgements

We thank the California State University, Long Beach Mechanical and Aerospace Engineering Department, including Jose Robles and Eric Park, who developed the experimental test bed and the force feedback models utilized in this study. We also thank NASA Ames Research Center for facilitating the collection of data on their premises, as well as the employees and interns of San Jose State University Research Foundation that served as participants.

References

[1] Federal Aviation Administration. (2011). FAA aerospace forecast: Fiscal years 2011-2031. Washington, DC: Author.
[2] Prevot, T., Homola, J., & Mercer, J. (2008). Human-in-the-loop evaluation of ground-based automated separation assurance for NextGen. Paper presented at the 26th Congress of International Council of Aeronautical Sciences, Anchorage, AK.
[3] Joint Planning and Development Office. (2010). Concept of operations for the Next Generation Air Transportation System version 3.2.
[4] McAnulty, D.M., & Zingale, C.M. (2005). Pilot-based spacing and separation on approach to landing: The effect on air traffic controller workload and performance. Washington, DC: Federal Aviation Administration.
[5] Granada, S., Dao, A.Q., Wong, D., Johnson, W.W., & Battiste, V. (2005). Development and integration of a human-centered volumetric cockpit display for distributed air-ground operations. In Proceedings of the 12th International Symposium on Aviation Psychology (pp. 229-284). Oklahoma City, OK: FAA Academy.
[6] Dao, A.-Q. V., Brandt, S.L., Battiste, V., Vu, K.-P. L., Strybel, T., & Johnson, W.W. (2009). The impact of automation assisted aircraft separation on situation awareness. Paper presented at the Human-Computer Interaction International Conference, San Diego, CA.
[7] Akamatsu, M., & Sato, S. (1994). A multi-modal mouse with tactile and force feedback. International Journal of Human-Computer Studies, 40, 443-453.
[8] Fitts, P.M. (1954). The information capacity of the human motor system in controlling the amplitude of movement. Journal of Experimental Psychology, 47, 381-391.
[9] Meyer, D.E., Abrams, R.A., Kornblum, S., Wright, C.E., & Smith, J.E.K. (1988). Optimality in human motor performance: Ideal control of rapid aimed movements. Psychological Review, 95, 340-370.
[10] Griffiths, P., & Gillespie, R.B. (2005). Sharing control between human and automation using haptic interfaces: Primary and secondary task performance benefits. Human Factors, 47, 574-590.
[11] He, F., & Agah, A. (2001). Multi-modal human interactions with an intelligent interface utilizing images, sounds, and force feedback. Journal of Intelligent and Robotic Systems, 32, 171-190.
[12] Dennerlein, J.T., & Yang, M.C. (2001). Haptic force-feedback devices for the office computer: Performance and musculoskeletal loading issues. Human Factors, 43, 278-286.
[13] Ahlstrom, D. (2005). Modeling and improving selection in cascading pull-down menus using Fitts' law, the steering law and force fields. Paper presented at the Conference on Human Factors in Computing Systems, Portland, OR.
[14] Oakley, I., McGee, M.R., Brewster, S., & Gray, P. (2000). Putting the feel in "look and feel." Paper presented at the CHI Conference on Human Factors in Computing Systems, The Hague, Netherlands.
[15] Tornil, B., & Baptiste-Jessel, N. (2005). Force feedback and performance in a point-and-click task. Paper presented at the International Conference on Multimodal Interaction, Trento, Italy.
[16] Rorie, R.C., Vu, K. P. L., Marayong, P., Robles, J., Strybel, T. Z., & Battiste, V. (2013). Effects of type and strength of force feedback on movement time in a target selection task. In Proceedings of the Human Factors and Ergonomics Society Annual Meeting (pp. 36-40). San Diego, CA: SAGE.
[17] Keates, S., Langdon, P., Clarkson, P.J., & Robinson P. (2000). Investigating the use of force feedback for motion-impaired users. In Proceedings of the 6th ERCIM Workshop (pp. 207-212). Florence, Italy: EDC.
[18] Hasser, C., & Goldenberg, A. (1998). User performance in a GUI pointing task with a low-cost force-feedback computer mouse. In Proceedings of the ASME Dynamic Systems and Control Division (pp. 151-156). New York, NY: American Society of Mechanical Engineers.
[19] Eberhardt, S., Neverov, M., West, T., & Sanders, C. (1997). Force reflection for wimps: A button acquisition experiment. In Proceedings of the 6th Annual Symposium on Haptic Interfaces, International Mechanical Engineering and Exposition. Dallas, TX.
[20] Tornil, B., & Baptiste-Jessel, N. (2005). Force feedback and performance in a point-and-click task. Paper presented at the International Conference on Multimodal Interaction, Trento, Italy.
[21] Novint Technologies, Inc. (2012). Retrieved from: http://www.novint.com/index.php/novintfalcon
[22] Rorie, R.C., Bertolotti, H., Strybel, T., Vu, K.-P.L., Marayong, P., & Robles, J. (2012). Effect of force feedback on an aimed movement task. Paper presented at the 4th International Conference on Applied Human Factors and Ergonomics, San Francisco, CA.
[23] Friedman-Hill, S.R., Robertson, L.C., Desimone, R., & Ungerleider, L.G. (2003). Posterior parietal cortex and the filter of distractors. Proceedings of the National Academy of Sciences of the United States of America, 100(7), 4263-4268.
[24] Gál, V., Kozák, L. R., Kóbor, I., Bankó, É. M., Serences, J. T., & Vidnyánszky, Z. (2009). Learning to filter out visual distractors. European Journal Of Neuroscience, 29(8), 1723-1731.
[25] Fischer, M.H., & Adam, J.J. (2000). Distractor effects on pointing: The role of spatial layout. Experimental Brain Research, 136, 507-513.
[26] Robles, J., Sguerri, M., Rorie, R.C., Vu, K.-P., Strybel, T., & Marayong, P. (2012). Integration framework for NASA NextGen volumetric cockpit situation display with haptic feedback. Paper presented at the International Conference on Robotics and Automation, Saint Paul, MN.
[27] Monk, K. J. (2014). Effects of distractors and force feedback on an aimed movement task in a CDTI environment. California State University, Long Beach.