Designing Interactions for Multiple Monitor Environments

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Background

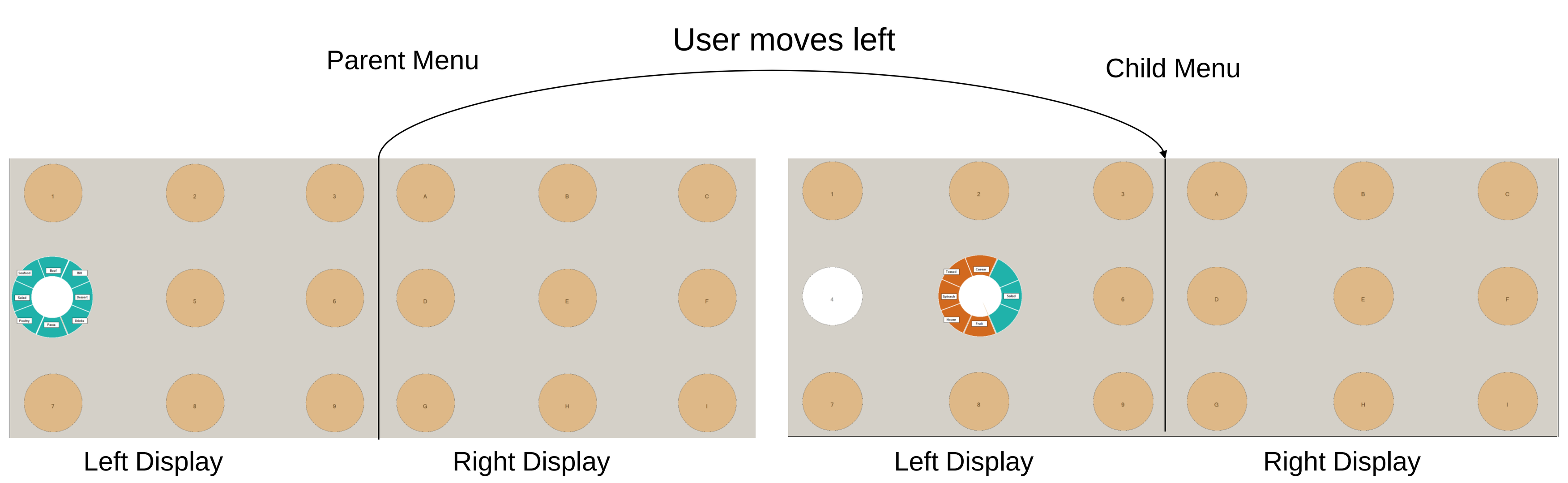
As users interact with increasing amounts of information on their computers, they can quickly become overwhelmed with the task of effectively organizing this information. A common coping strategy to this dilemma is to increase the number of displays available to their computer. Interestingly, previous research suggests that users in multi-display environments avoid interacting between displays by rarely stretching applications across multiple displays. Instead, users purposefully distribute applications among the available display devices such that applications relevant to a primary task are localized to a "primary display" and other applications are placed on ancillary displays [2]. While this approach helps to avoid cross-monitor interactions it fails to address interaction components which can force users to interact across displays. Menu interactions are an example of such components. Such interactions are particularly interesting given the ubiquity of menu-based interactions.

To investigate the impact of cross-monitor interactions on users' performances and preferences, we developed Pie m2 (Pie-menu for multiple-monitors); a hierarchical pie-menu implementation capable of exhibiting various behaviors when it collided with display boundaries.

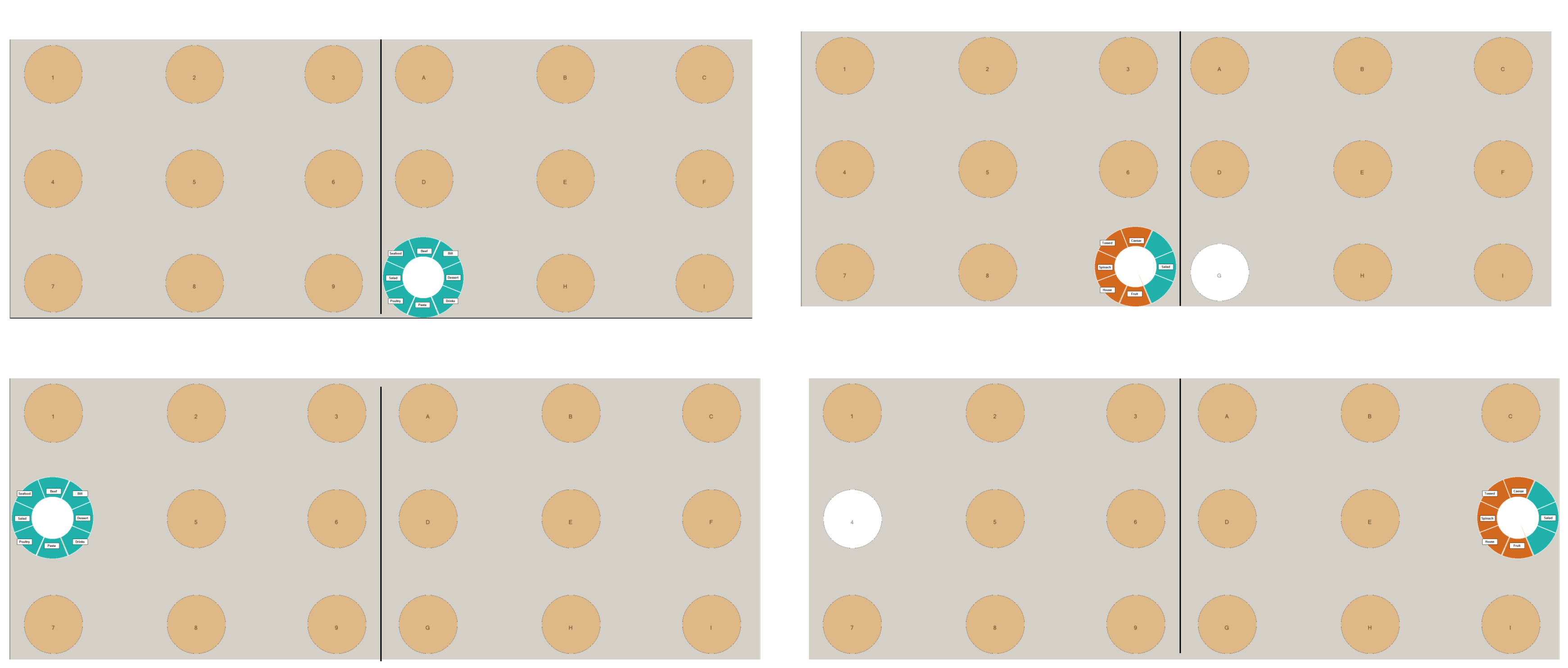
Description of Pie m^2

Pie menus are larger than traditional linear menus and are thus more likely to collide with display boundaries [1]. In the current version of pie m^2, menus resolve collisions with display boundaries in various ways. If a parent menu collides with a display boundary it is automatically adjusted so that it is fully displayed on the display on which the menu was initially invoked. However, if a child menu collides with a display boundary, then both the parent and child menu were repositioned according to one of two possible techniques (Centering and Warping).

When the Centering technique (CT) was used, both parent and child menus were always repositioned to the center of the display.



The goal of Warping technique (WT) was to preserve the benefits of using pie menus [1] in a multi display environment. Specifically, our menus treated display space as a circular plane. If the child menu collided with a display boundary, the parent and child menus were repositioned such that they naturally flowed to the new display and preserved users' initial directional movements.



Experiment

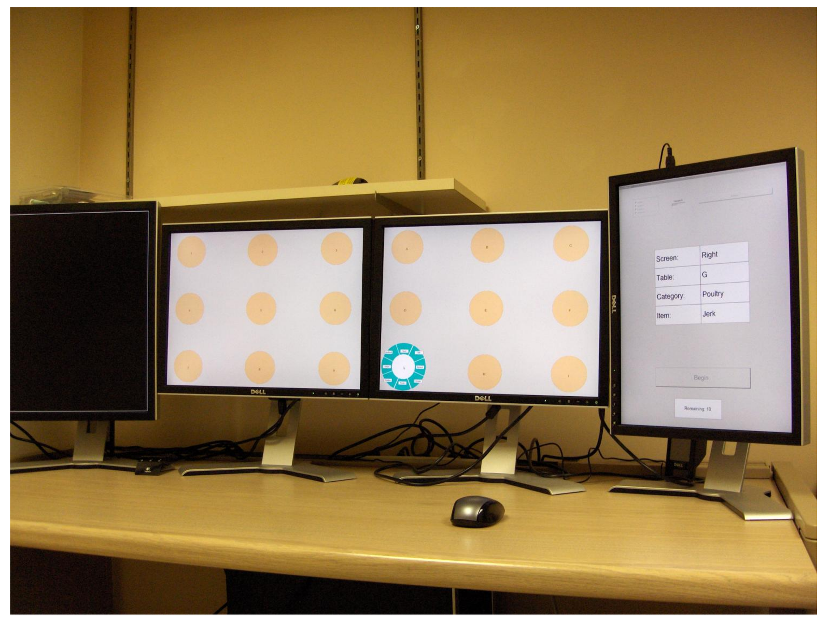
To evaluate the two adjustment algorithms we asked participants to complete a menu selection task. During this task participants were prompted to select specific menu items from a two level-menu. We used a 2 2 mixed factors design, manipulating adjustment technique (CT and WT) between subjects and number of displays (1 and 2) within subjects. Participants completed a total of 270 trials distributed in the following manner:

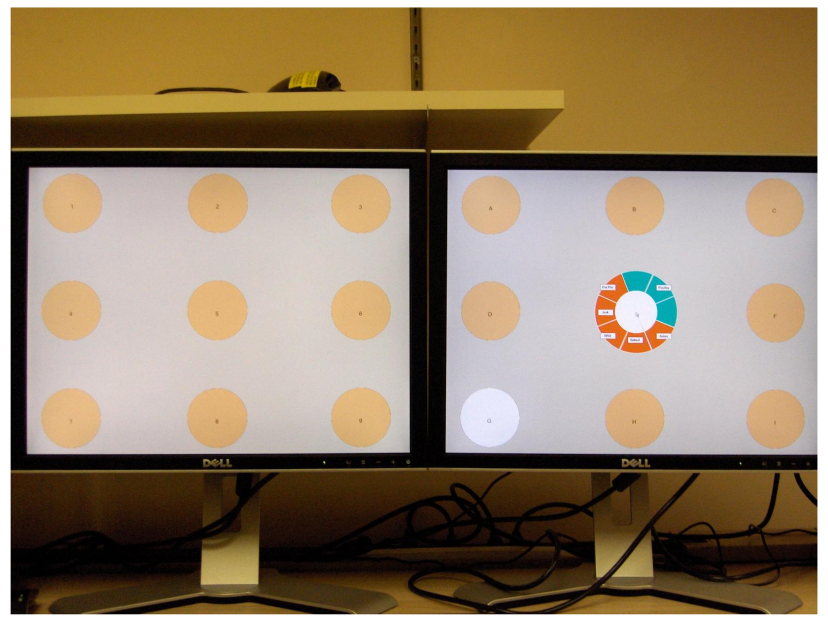
Single Display Trials

9 practice trials	9 pre-test trials	72 single-display	9 post-test trials

Dual Display Trials

9 practice trials	9 pre-test trials	144 dual-display	9 post-test trials





Results

We analyzed three dependent measures: the number of errors per trial, the total number of selections per trial, and the overall time to select the target item. Of these measures only participants' selection times provided any meaningful information.

A 2 2 2 Mixed factors ANOVA (Display Count Order Adjustment Type) indicated a significant main effect of order $F(1,60) = 140.10$, $p < .01$ (Figure 1).

A 2 2 2 Mixed factors ANOVA (Adjustment needed Display Count Adjustment Type) was conducted to analyze the impact of performing adjustments. A significant main effect of adjustment needed was found $F(1,60) = 194$, $p < .01$) (Figure 2).

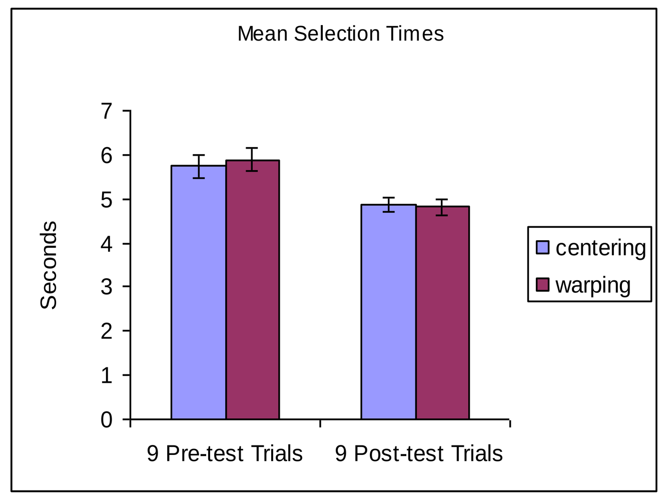


Figure 1. Participants' mean selection times for the pre-test and post-test trials for both adjustment algorithms.

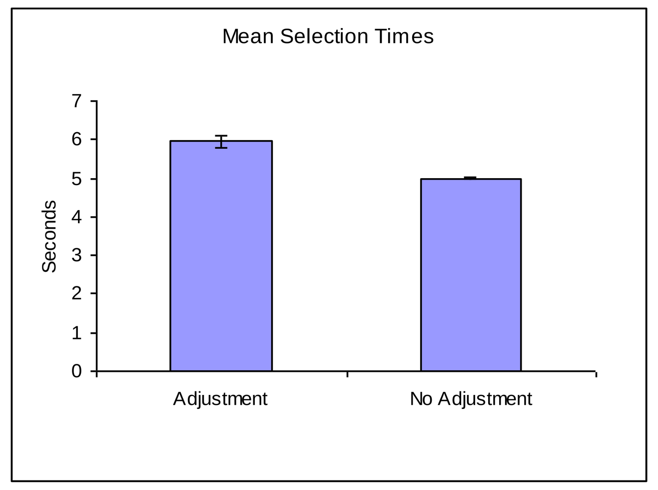


Figure 2. Comparison of the mean selection times for trials requiring adjustments and trials not requiring an adjustment.

Results (cont.)

The effects of cross-monitor interactions were assessed in two ways: First, the mean selection times for trials requiring cross-monitor interactions were compared to trials requiring adjustments that did not require cross-monitor interactions. A repeated measures ANOVA indicated a significant effect of adjustment needed $F(1,29) = 188.5$, $p < .01$ (Figure 3).

Second, trials requiring cross-monitor interactions were compared to identical trials in the Centering condition, which never resulted in cross-monitor interactions. A one-way ANOVA indicated the main effect of adjustment technique approached significance $F(3,37) = 3.37$, $p = .07$ (Figure 4).

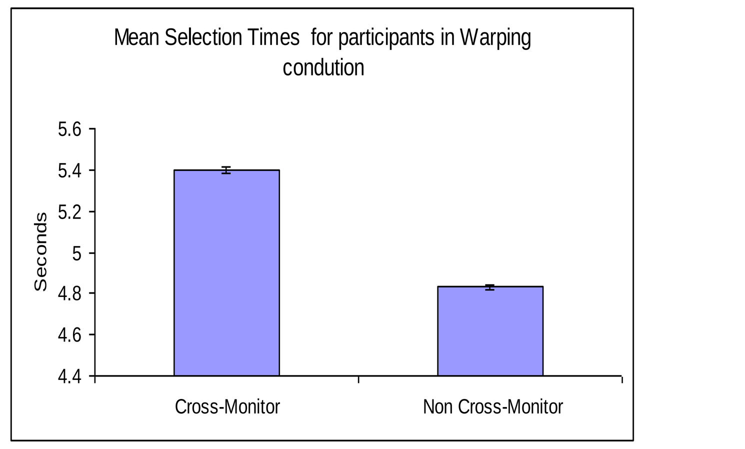


Figure 3. Comparison of participants' mean selection times, in the warping condition, for trials which resulted in a cross-monitor interaction.

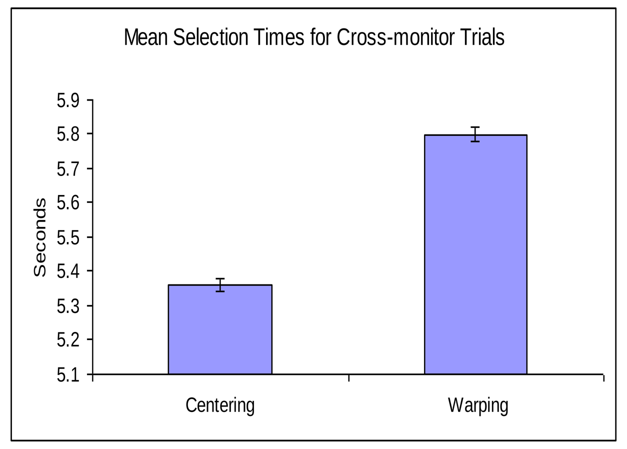


Figure 4. Comparison of Mean selection times for trials requiring cross-monitor interactions to identical trials not requiring cross-monitor interactions.

Survey Results

After participants completed all selection trials they completed a short questionnaire regarding their experience. Questions were recorded on a five-point-scale and scored according to their distance from the midpoint. Positive numbers indicate agreement and negative numbers indicate disagreement.

Survey Question	Center	Warp
Ease of selecting items from menu	0.75**	0.64*
Ease of predicting root menu location	0.69	0.46
Ease of predicting child menu location	0.15**	-0.18
Ease of predicting child menu following collision	0.56**	.07**
Collisions were handled appropriately	0.72**	.71**
Menus were well organized	0.91**	.10**
Experienced with circular menus	-0.78**	-1.00**
Experienced with multi-display environments	-0.72**	-.86**
Child menu randomly placed following collision	-0.72**	0.14

Tests indicate difference from no opinion (0)
* $p < .05$ ** $p < .01$

Note: Descriptions differ from actual wording in questionnaires

Discussion

The results of the present experiment show that while both adjustment techniques are equally learnable, participants both performed better and preferred the centering adjustments over the warping adjustments. Together, these results could imply that developers should avoid interactions which cross display boundaries. Alternatively, these findings could be the result of warping, as opposed to a difficulty with crossing display boundaries. That is, the act of warping a menu impeded participants' selection performances. Evidence for this claim can be seen in participants' beliefs that warped menus were randomly repositioned following collisions. Currently, we are investigating this possibility with traditional linear menus.

References

[1] Callahan, J., Hopkins, D., Weiser, M., Shneiderman, B. (1988). An Empirical Comparison of Pie Vs. Linear Menus. *CHI, 95-100.*

[2] Grudin, J. (2001). Partitioning Digital Worlds: Focal and peripheral awareness in multiple monitor use. *CHI* (3)1. 458-465.