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EFFECTS OF CONTROL TYPE AND PANEL ANGLE ON KITCHEN APPLIANCE USABILITY: A COMPARATIVE STUDY OF KNOB AND TOUCHSCREEN PANELS

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This study empirically examined whether panel angle effects on kitchen appliance control panel usability vary by control type. Two representative types—cooker knobs and touchscreen panels—were tested at four angles (0°, 30°, 60°, 90°), reflecting common configurations in commercial ranges. Usability was assessed through visibility, physical comfort, and preference. Twenty participants performed heat-level adjustment tasks at each angle and rated all measures. Results showed: (1) significant interaction effects between control type and panel angle across all criteria, and (2) substantial main effects of panel angle on evaluation scores. Knob panels achieved higher ratings at steeper angles, while touchscreen panels performed better at flatter angles. These findings provide ergonomic guidance for designing control interfaces that integrate both knobs and touchscreens. Proper panel angle design can enhance visual accessibility, reduce bodily strain, and help prevent musculoskeletal disorders during prolonged and repetitive use.

Keywords: control panel angle; kitchen appliances; cooker knobs; touchscreen panels; usability evaluation.

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1. INTRODUCTION

Representative types of control panels in commercial kitchen appliances, such as slide-in ranges, ovens, and cooktops, include cooker knobs and touchscreen panels. Multifunctional products that combine cooktops and ovens, such as slide-in/freestanding ranges, often utilize both cooker knobs and touchscreen panels to accommodate diverse operational requirements.

Panel angle represents one of the most important physical design parameters of control panels; however, it varies significantly across brands and products due to the absence of established specifications or standards. For instance, cooktop control panels are manufactured with diverse angular configurations (including 0°, 15°, 30°, 60°, 90°, among others) across multiple manufacturers, including GE, Bosch, KitchenAid, Frigidaire, Café, Samsung, and LG. Panel angle can be considered a critical factor that determines the overall usability of kitchen appliances by significantly affecting visibility and physical comfort during product use (Albin & McLoone, 2014; Chiang & Liu, 2016; Chiu *et al.,* 2015; Huang *et al.,* 2024; Rungkitlertsakul *et al.,* 2023; Schultz *et al.,* 1998; Vasavada *et al.,* 2015; Young *et al.,* 2012).

The influence of panel angle on usability may vary according to the control type employed (cooker knobs, touchscreen panels, etc.). When panel angle is inappropriate, usability becomes compromised, and in contexts involving continuous and repetitive use, negative effects such as musculoskeletal disorders may be further exacerbated (Chaffin, 1973; Chiang & Liu, 2016; Harms-Ringdahl & Ekholm, 1986; Keir *et al.,* 2007; Korpinen *et al.,* 2013; Lau *et al.,* 2010; Lozano *et al.,* 2011; Rempel & Horie, 1994; Sengsoon *et al.,* 2025; Shin & Zhu, 2011; Tapanya *et al.,* 2021; Vahedi *et al.,* 2024; Vasavada *et al.,* 2015; Villanueva *et al.,* 1997; Yasshwi *et al.,* 2025; Yen, 2011; Yip *et al.,* 2008). Furthermore, given that kitchen appliances can be directly related to fire hazards (Pollack, 2019), inappropriate panel angles may potentially cause critical consequences by reducing user response time in emergency situations.

Although extensive research has been conducted on the ergonomic design of control panels, studies have focused primarily on smartphones and tablet PCs (Albin & McLoone, 2014; Murata & Iwase, 2005; Rungkitlertsakul *et al.,* 2023; Schultz *et al.,* 1998; Tomita *et al.,* 2022; Vannajak & Vannajak, 2023; Xiong *et al.,* 2021; Young *et al.,* 2012), while research addressing home appliance applications remains relatively limited. Current regulatory frameworks and design specifications (ANSI Z 21.1, American National Standard for Household Cooking Gas Appliances, 2010; ANSI/UL 858, Standard for Household Electric Ranges, 2009; US Consumer Product Safety Commission, 2006) for kitchen appliance usage remain restricted in scope and emphasize primarily safety considerations. Son & Beck (2022) and Son *et al.* (2024) conducted research on the ergonomic design of kitchen appliance control panels, proposing optimal angle design ranges for cooker knob panels and touchscreen panels, respectively, to enhance usability and safety. However, a comprehensive analysis of how panel angle influences on usability varies according to control type, and the underlying causes of these differences have not been undertaken. A thorough understanding of the two representative control types (knobs and touchscreen panels) commonly utilized in commercial products could provide substantial guidance for the ergonomic design of kitchen appliances.

Therefore, this study investigated how the influence of panel angle on product usability varies according to control type. Two control types widely utilized in commercial products (knobs and touchscreen panels) were examined, and four panel angle levels (0°, 30°, 60°, and 90°) were evaluated. To assess usability, subjective evaluation measures including visibility, physical comfort, and preference were employed, consistent with established methodologies in prior usability evaluation studies (Albin & McLoone, 2014; Chiang & Liu, 2016; Chiu *et al.,* 2015; Rungkitlertsakul *et al.,* 2023; Schultz *et al.,* 1998; Tang *et al.,* 2021; Son *et al.,* 2013). The experimental design and research methods were adapted from the approaches established in the aforementioned studies by Son & Beck (2022) and Son *et al.* (2024).

2. METHODS

2.1 Participants

Twenty individuals (seven men and thirteen women) aged between their 20s and 40s participated in the study. All participants were Americans with at least one year of experience operating slide-in/freestanding ranges. Participant demographics showed a mean age of 33.3 years (range: 22–47 years, SD = 6.81) and a mean height of 173 cm (range: 155–192 cm, SD = 10.6). Exclusion criteria eliminated individuals with any history of musculoskeletal or neurological disorders. Written informed consent was obtained from each participant prior to study commencement.

2.2 Study design and experimental variables

A controlled laboratory environment replicating authentic kitchen conditions was established for this investigation. Given that standard installation heights for commercial slide-in/freestanding ranges from manufacturers such as Samsung, LG, Whirlpool, Bosch, and Miele typically range from 800 to 900 mm, the panel height (H) was set at 850 mm, representing the average installation height. To achieve the experimental objectives, adjustable panel mockups were employed rather than complete commercial products. The horizontal distance (D) between the appliance and user was fixed at 200 mm, based on pilot testing that determined typical user-to-product distances during kitchen appliance operation. Figure 1 illustrates the experimental setup used in this study.

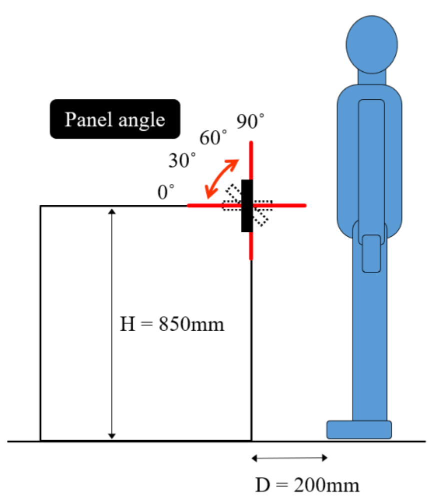
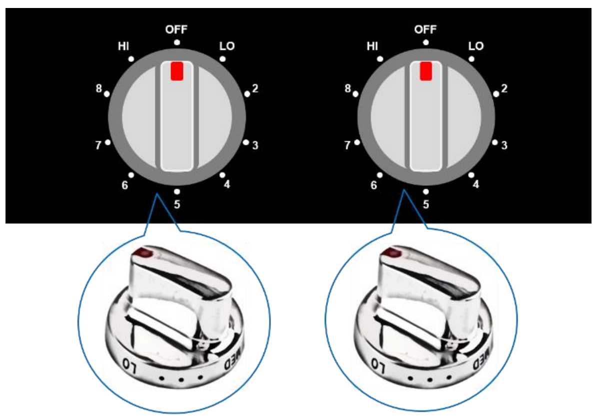


Figure 1. Experimental apparatus

Panel angle served as the independent variable with four levels: 0°, 30°, 60°, and 90°. Two distinct panel mockups were developed to closely resemble actual control interfaces commonly found in commercial kitchen appliances (Figure 2). The first mockup featured a knob panel capable of controlling two burners (left and right). Power levels were marked redundantly following the design approach used in most existing range products: (1) on the panel surface adjacent to each knob, and (2) on the lateral surface of the knob body. To adjust power levels, users pushed and turned the knob clockwise to select from nine power stages ranging from "LO" to "HI." The second mockup consisted of a touchscreen panel equipped with linear range sliders for operating two burners (left and right), with power levels displayed in red. Power level adjustment required initial activation of the 'Burner selection button' (Figure 2), followed by selection of the desired power setting between "LO" and "HI" through either direct value selection or drag-and-drop slider manipulation.

Three dependent variables were assessed: visibility, physical comfort, and preference, which represent commonly evaluated criteria in control panel usability research. Table 1 provides detailed descriptions of each variable and the corresponding participant questionnaire items.



(a) Knob panel

(b) Touchscreen panel

Figure 2. Control panel mockup

Table 1. Three dependent variables

Measures	Description	Question
Visibility	An assessment of how readily users could visually verify power level settings during panel operation	"How much do you agree with the statement that it was easy to see the power levels when operating the panels?"
Physical comfort	An evaluation of users' overall subjective comfort or discomfort experienced across different body regions during control panel manipulation	"How much do you agree with the statement that using the panel felt comfortable?"

Measures	Description	Question
Preference	An assessment of users' subjective satisfaction or dissatisfaction with the control panels	"How much do you agree with the statement that you preferred using this panel?"

Participants rated each measure using a 7-point Likert scale (Likert, 1932; Joshi *et al.,* 2015) as shown in Figure 3.

Rating	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Description	Strongly disagree	Disagree	Slightly disagree	Neutral	Slightly agree	Agree	Strongly agree

Figure 3. A 7-point Likert scale for subjective ratings of visibility, physical comfort, and preference

2.3 Procedures

The experimental procedure consisted of two primary tasks: knob panel operation and touchscreen panel operation. Prior to experimental trials, participants completed an orientation and training session to become familiar with the procedures.

The experiment followed a standardized protocol. Participants positioned themselves 200 mm from the panel interface. For the knob panel task, participants adjusted one of nine power settings as specified by the experimenter. Each participant completed four consecutive trials for each panel angle, with two trials for the left burner and two for the right burner. For the touchscreen panel task, participants adjusted to one of nine power settings randomly selected by the experimenter. The trial structure remained consistent: four repetitions per panel angle, alternating between left and right burner controls.

After completing all trials for each of the four panel angles, participants rated visibility, physical comfort, and preference using the 7-point Likert scale. The presentation order of panel angles was randomized for each participant to minimize order effects. Throughout task performance, participants were video-recorded from multiple angles to enable subsequent analysis of wrist and neck flexion/extension angles during panel manipulation.

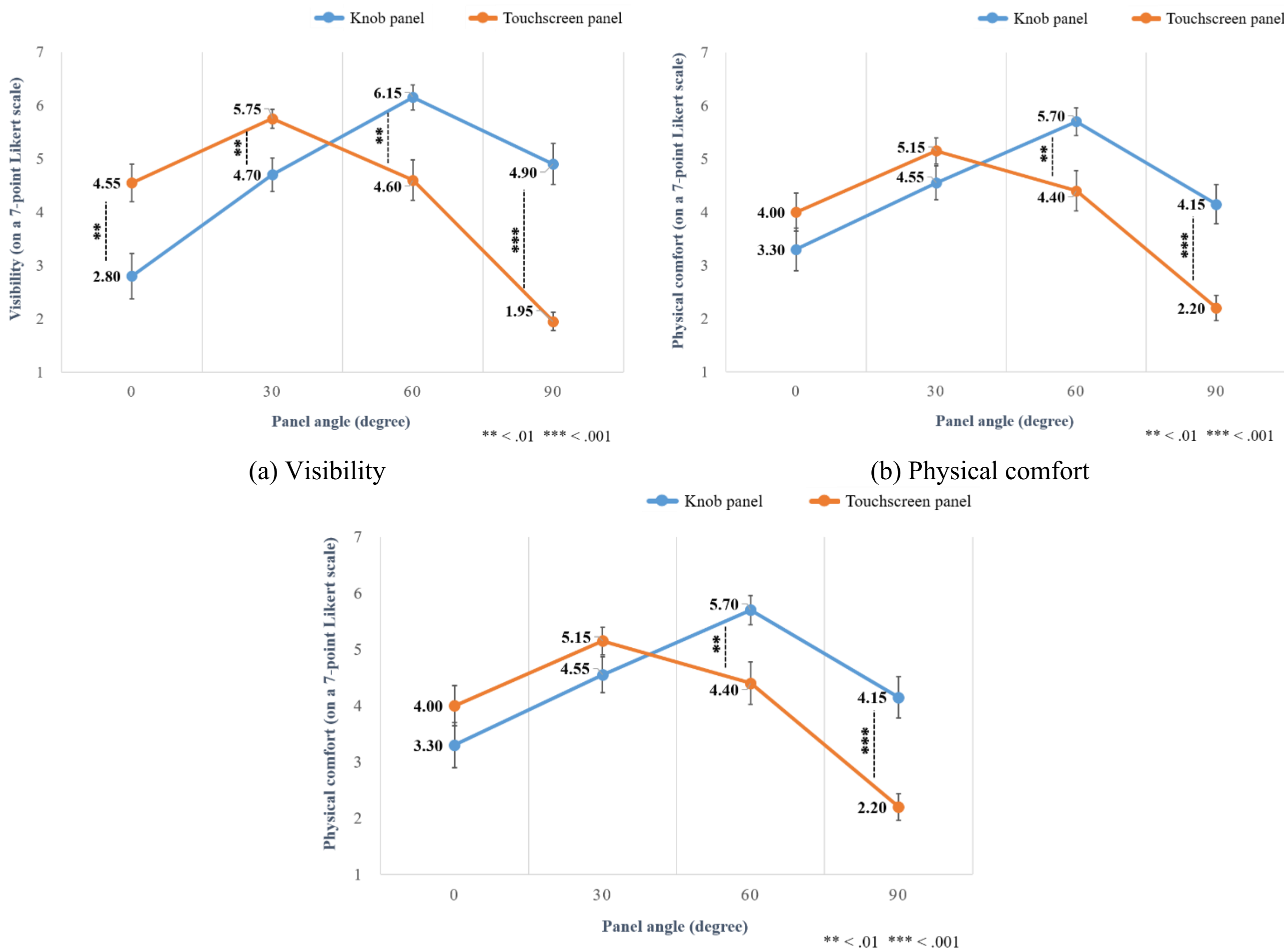
2.4 Data analyses

The three dependent variables (visibility, physical comfort, and preference) were analyzed using multivariate analyses of variance (MANOVAs) given their high intercorrelations. MANOVA is appropriate for situations with multiple correlated dependent variables, as it accounts for their covariance structure while controlling familywise error rate (Field, 2009). Following significant MANOVA results, analyses of variance (ANOVAs) were performed as follow-up tests with alpha levels adjusted to control Type I error rate. Sphericity assumptions were assessed using Mauchly's test for each ANOVA. When sphericity violations were detected, degrees of freedom were adjusted using the Greenhouse–Geisser correction when the sphericity estimate (ε) was less than 0.75, or the Huynh−Feldt correction when ε ≥ 0.75 (Field, 2009; Girden, 1992). For statistically significant ANOVA results, post hoc pairwise comparisons with Bonferroni corrections were performed to determine which panel angle pairs differed significantly in their mean values.

As supplementary analysis, separate two-way ANOVAs were conducted for each control type (knob panel and touchscreen panel) to determine whether panel angle effects on the dependent variables varied according to user height. Note that participants were categorized into two height groups: a "tall" group comprising twelve individuals and a "short" group consisting of eight individuals, with the division criterion established at 168 cm representing the mean height of US adults (Fryar *et al.,* 2021). All statistical analyses were conducted using IBM SPSS Statistics 28.0, with statistical significance set at $\alpha = .05$.

3. RESULTS AND DISCUSSION

Using Pillai's trace, it turned out that there was a significant effect of panel angle on the three dependent measures, $V = .58$, $F\ (9, 171) = 4.50$, $p < .001$, $\eta_p^2 = .19$. Separate univariate ANOVA results demonstrated statistically significant interaction effects between control type and panel angle for all three measures: visibility, $F\ (5, 95) = 25.9$, $p < .001$; physical comfort, $F\ (5, 95) = 13.4$, $p < .001$; and preference, $F\ (3.11, 59.1) = 24.4$, $p < .001$. Simple main effects for control type were also statistically significant for each dependent variable. Figures 4(a)–4(c) present the mean scores for each panel angle by control type, with asterisks indicating statistical significance in post hoc pairwise comparisons using Bonferroni corrections. Error bars represent one standard error above and below the mean.



(a) Visibility

(b) Physical comfort

(c) Preference

Figure 4. Effects of panel angle and control type on (a) visibility, (b) physical comfort, and (c) preference

Examination of overall trends revealed distinct patterns for each control type. For knob panels, panel angles from 30° to 90° yielded scores at or above 4 ("Neutral"), with 60° achieving scores exceeding 5 ("Slightly agree"). Conversely, for touchscreen panels, panel angles from 0° to 60° produced scores above 4 ("Neutral"), with 30° reaching scores higher than 5 ("Slightly agree").

The differences in subjective evaluation scores between control types stem from variations in how easily users can visually confirm power levels during operation and the distinct posture requirements of each control type. Post-hoc video analysis revealed key visibility differences. First, power level marking methods differed between control types. For knob panels, power levels were marked adjacent to the knob, whereas touchscreen panels clearly separated power control buttons from display locations (Figures 2a-2b). Consequently, knob operation involved additional visual obstruction due to pinch grip, where power level markings were partially obscured by the hand and forearm, particularly pronounced at gentle panel angles. At 0°, knob panels scored below 3 ("Slightly disagree") while touchscreen panels exceeded 4 ("Neutral"), showing statistically significant differences.

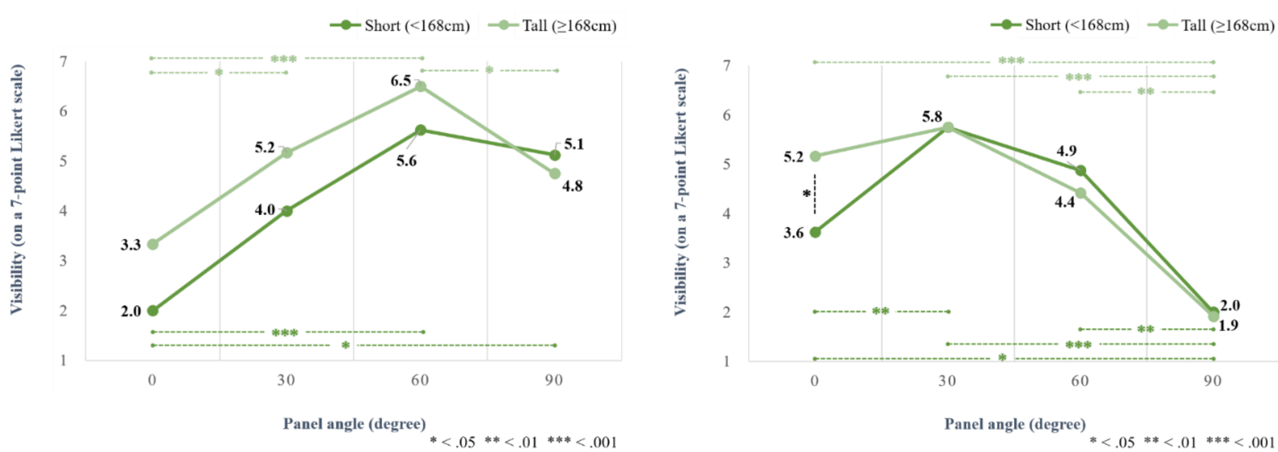
Conversely, knob panels benefited from redundant power level markings on the knob body side (Figure 2a), facilitating power level confirmation during vertical viewing. At 90°, knob panels achieved scores near 5 ("Slightly agree") while touchscreen panels approached 2 ("Disagree"), with significant differences observed.

Operational posture differences further explain the findings. Knob operation required a pinch grip, while touchscreen operation utilized fingertips with extended palms. Movement patterns also differed significantly: knob operation involved grasping and rotating over 300° with forearm pronation/supination, creating substantial movement variations. Touchscreen operation required only fingertip touching and short-distance sliding. These grip and operational differences affected physical comfort, particularly at gentle angles like 0°. Knob operation at 0° induced elbow/shoulder elevation, especially pronounced in shorter participants, while touchscreen operation at 0° involved minimal wrist bending and remained relatively comfortable. Physical comfort scores at 0° showed knob panels near 3 ("Slightly disagree") versus touchscreen panels at 4 ("Neutral").

At steeper angles (60° or 90°), knob operation became advantageous for physical comfort, related to visibility differences. Touchscreen operation at steep angles, especially 90°, rendered panels barely visible from above, requiring compensatory body movements such as leaning back or bending the waist and knees, increasing overall discomfort. At 60°, knob panels scored near 6 ("Agree") while touchscreen panels fell below 5 ("Slightly agree"). At 90°, knob panels exceeded 4 ("Neutral") while touchscreen panels approached 2 ("Disagree").

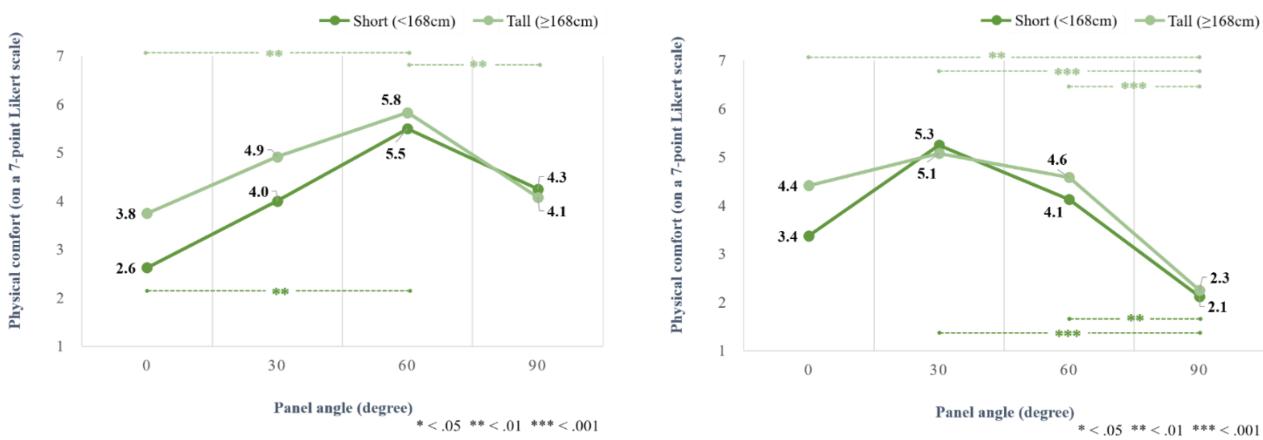
Beyond visibility and physical comfort, familiarity derived from previous experience with existing appliances contributed to evaluation differences. According to the cognitive psychologists' theory (Kaplan and Kaplan, 1982), familiarity is “the relationship between an individual and something that individual has had considerable experience with. The experience is sufficient to advance to the development of an internal model of that something.” The feeling of familiarity is derived from an individual's prior experience that is stored in one's memory. The increase of familiarity will lead to the strengthening of connections among less connected features (Son *et al.*, 2002; Zhang *et al.*, 2016). Relatedly, Laurel (1990) suggested that the operation of an interactive system is best achieved by means of a metaphor or analogy, which indicates the importance of familiarity. Being familiar with a system means we are ready to operate it in an appropriate way based on our prior experiences (Herstad and Holone, 2012). Considering the aforementioned literature, it can be inferred that under touchscreen panel experimental conditions, participants could have achieved more familiar interactions at flat panel angles based on their prior experience with smartphones and tablet PCs, where panels are typically oriented horizontally during operations such as typing. Conversely, for knob panel conditions, since knobs in most existing range products are typically positioned at approximately 90°, it is conceivable that participants would have experienced more familiar interactions at steep panel angles based on this prior exposure. In contrast, participants may have felt unfamiliar with gentle panel angles such as 0° from the outset, as this configuration deviates from conventional knob positioning. Indeed, during our experiment, some participants expressed discomfort and negative reactions even before attempting to operate knobs at 0°, suggesting an immediate sense of unfamiliarity with this unconventional orientation.

It is noteworthy that the simple main effects for height in the touchscreen panel were significant in the gentle panel angle range. As mentioned earlier, the cause can be found in the fact that operational postures and power level marking methods differed between the two control types when operating the panels. For the touchscreen panel, since the areas for fingertip touching and power level display were clearly separated, there was no visual interference from the back of the hand and lower arm across all angle conditions, including gentle panel angles. Consequently, differences in viewing angle according to participants' height could fully influence the visibility and preference evaluation results. However, for knob operation, visual interference due to pinch grip existed commonly for both tall and short groups in gentle panel angle ranges, especially at 0°. Therefore, differences in viewing angle according to participants' height could not be fully reflected in gentle panel angle ranges. For this reason, it can be inferred that the interaction effect between panel angle and height group, which was significant in touchscreen panel operation, was not significant in the knob panel.



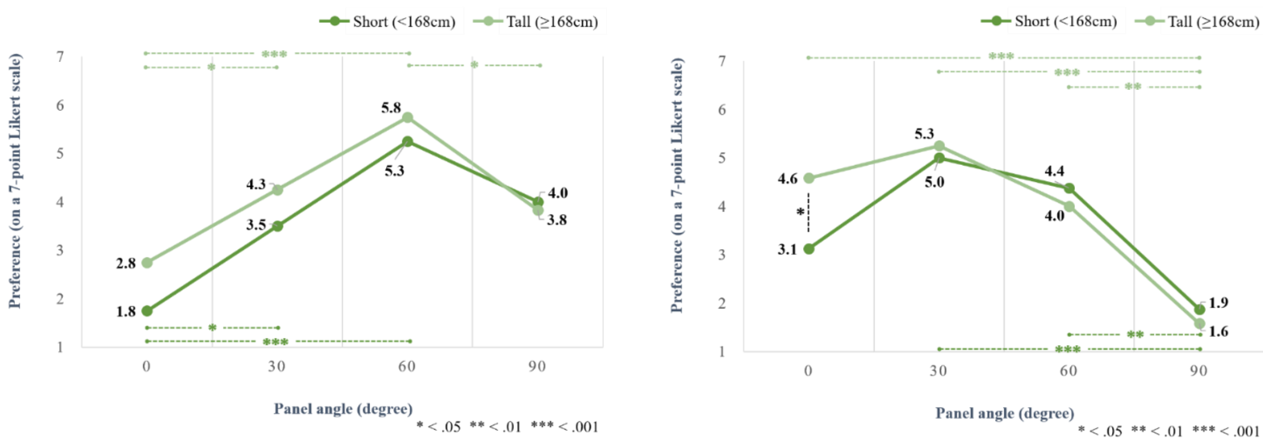
(a) Knob panel (b) Touchscreen panel

Figure 5. Effects of panel angle and height on visibility



(a) Knob panel (b) Touchscreen panel

Figure 6. Effects of panel angle and height on physical comfort



(a) Knob panel (b) Touchscreen panel

Figure 7. Effects of panel angle and height on preference

4. CONCLUSION

The current study experimentally examined the influence of control type and panel angle on usability measures through subjective assessments of visibility, physical comfort, and preference across four distinct panel angles (0°, 30°, 60°, and 90°) using a 7-point Likert scale.

The data analyses revealed significant interaction effects between control type and panel angle for all three subjective evaluation measures (Figures 4a–4c), confirming that panel angle influence varies according to control type. For knob panels, panel angles from 30° to 90° yielded scores of 4 ("Neutral") or higher, with optimal performance at 60°. For touchscreen panels, panel angles from 0° to 60° produced scores above 4 ("Neutral"), with peak performance at 30°. These findings align with ergonomic design ranges described in previous studies (Son & Beck, 2022; Son *et al.,* 2024), which considered visibility aspects such as user line of sight and display tilt angle, as well as physical comfort factors including range of motion that minimizes strain on wrist, elbow, and shoulder joints.

This research provides several practical and theoretical contributions. First, the results of this study demonstrated that the influence of panel angle on visibility, physical comfort, and preference showed different patterns according to control type. These differences can be attributed to the fact that grip, posture, and movements adopted by users vary according to the two control types. Therefore, the findings of this study suggest that appropriate interaction/product design should be implemented according to control types. If panels utilize both control types together, it would be optimal to design panels with different angles according to each recommended range. When such a design is constrained, it is required to design panels considering the common recommended range of the two control types. Second, the optimal panel angle design ranges for the two control types were derived by taking into account ergonomic design factors such as visibility and physical comfort. These findings could be applied to ergonomic kitchen appliance panel design and could contribute to preventing musculoskeletal disorders resulting from continuous and repetitive use.

Several limitations of the current study are recognized alongside recommendations for future research directions. First, this study only considered several discrete panel angles; however, future research could design experiments to allow participants to directly explore optimal and acceptable angle ranges within the continuous range of 0° to 90°. Such a self-selected user design approach would be meaningful in that it considers all possible panel angle design ranges from 0° to 90°, and additional new insights are expected to be obtained. Second, this study explored differences in usability according to panel angle as the main design variable. In addition to this, various other design variables, such as the spatial arrangement of knobs, knob shapes, including linear and circular knobs, and power level label marking methods, can also be considered important factors that may affect usability. Therefore, if comprehensive research including these factors were conducted, a more meaningful analysis would be possible. Lastly, this study exclusively recruited American participants. As anthropometric characteristics may differ across populations, additional research with international participants is needed to validate the generalizability of our findings to other countries and ethnic groups.

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