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The Impact of Feedback Design on Cognitive Effort, Usability, and Technology Use

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Completed Research

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Abstract

This study uses feedback design to explore the relationship between cognitive effort, usability, and behavior intention. We developed a decision aid, FoodGlance, which help users in making healthy food selection. We created two feedback designs for decision aid. The first feedback design scans the nutrition fact label and displays the information in the form of a pop-up. The second feedback used audio augmented reality along with the pop-up. Our results showed that cognitive effort had an impact on behavior intention; this impact was mediated by usability. However, this relationship was significant only when the task condition required high cognitive effort and had low usability. The two feedback designs significantly reduced cognitive effort in the decision-making process and increased usability. When participants used the pop-up feedback design, the mediating role of usability vanished. When the participant used pop-up with audio feedback, usability was no longer a player in our proposed model.

Keywords

Decision support system, feedback design, behavior change, decision making, nutrition facts label, audio augmented reality, health and wellness.

Introduction

This research examines the effects of different feedback designs on the relationship between cognitive effort, usability, and behavior intention. Feedback is the information about the decision-making process that help users in selecting outcome (Te'eni 1991). Feedback design is one of the crucial steps of creating a decision support system. The feedback has an impact on the user's performance (Chapanis 1964), but this impact is not always positive (Jacoby, Mazursky, Troutman, and Kuss 1984). Recent technological advancements enable us to deliver feedback in unique ways. One such technology is audio augmented reality (Audio AR). Audio AR is continuously growing as a medium for communicating an additional layer of information about a user's environment. In fact, audio AR is becoming an important selling feature in wearable audio devices such as headphones (Stewart 2019; Bullard 2019). We developed a decision aid, FoodGlance, which scans a nutrition fact label and converts nutrition information into personalized visual pop-up feedback. We used audio AR to design an audio feedback mechanism. Our previous research showed that while users liked both visual and audio feedback as separate mechanisms, the combination of both feedback mechanisms provided the most favorable user experience (Jain and Djamasbi 2019). In this study, we extend our previous findings by examining the role that the feedback mechanism plays on impacting the relationship between cognitive effort, usability, and behavioral intention. Prior research suggests that cognitive effort is likely to influence usability and that usability is likely to impact behavioral intention (Holden and Rada 2011; Djamasbi, Li, Traietti, Tran, Valcour, Whyatt, and Yuan 2015). To test this possibility, we conducted an exploratory study that examines how these variables (cognitive effort, usability, and behavioral intention) are related and whether feedback design influences the relationship between these variables.

Background

One of the widely used models to predict technology use is the Technology Acceptance Model (TAM). According to TAM, perceived ease of use and perceived usefulness influence the user's attitude, which in turn has an effect on behavioral intent (Davis, Bagozzi, and Warshaw 1989). However, Holden and Rada (2011) argue that the addition of perceived usability can uncover some of the unexplained variances in TAM. They found that the incorporation of perceived usability was more influential to TAM elements. Based on these findings, we want to explore the influence of cognitive effort on usability and behavior intention in this research. Djamasbi et al. (2015) found usability to have a strong influence on the intent to recommend. If a user has the intent to recommend, they are likely to have the intention to use. Therefore, in this research, we also want to explore the influence of usability on behavior intention, and if it has a mediation effect on the relationship between cognitive effort and usability.

The Decision Support System

Research shows that people often find nutrition facts labels difficult to understand and use (Cowburn and Stockley 2005; Temple and Fraser 2014). A nutrition facts label lists the nutrients present in a food product along with their corresponding amount. This information is mostly in the form of numbers, and consumers must interpret these numbers to determine if a product is healthy for them to consume. While the interpretation of nutrition facts for a single nutrient in a single product can be made quickly with simple calculations, it becomes cumbersome when people need to keep track of calculation for multiple nutrients and/or when they are considering more than one product (Cowburn and Stockley 2005).

We developed FoodGlance, to provide a less effortful process for people to make healthy decisions, using the nutrition facts label. Based on user dietary needs (which can be set up in the app), we developed two feedback designs for the FoodGlance app. The first feedback displays information in the form of a screen pop-up. The pop-up includes nutrient name, amount, and a color-coded thumbs up/thumbs down. The design principle most researchers use for guiding users to perform intended behavior is 'suggestion' (Torning and Oinas-Kukkonen 2009). Thumbs up and thumbs down icons are not only well known for suggesting good and bad, respectively, but also provide a suitable feedback mechanism that is essential in altering and reinforcing behavior (Nguyen, Ruiz, Wilson, Strong, and Djamasbi 2018). Previous research also suggests the use of traffic style color-coding to make icons more understandable (Temple and Fraser 2014). Therefore, the static pop-up feedback design displays green thumbs up and red thumbs down for nutrients in healthy and unhealthy amount, respectively. In our previous research, these color-coded thumbs up and thumbs down were deciding cues for the participants (Jain and Djamasbi 2019). Second feedback delivers audio information along with displaying information as a screen pop-up. We translated thumbs up as audio message: <*nutrient*> is in good amount, and for thumbs down: <*nutrient*> is in bad amount. For delivering the audio feedback, the app uses Bose audio AR glasses (Bose n.d.).

Users interact with these feedbacks after scanning the nutrition facts label with the app. The app uses optical character recognition to extract the nutrient information from the nutrition facts label. This information is then converted into percent daily value (%DV). The percent daily value shows the contribution of a particular nutrient towards the daily intake of that nutrient, in one serving of the food product (FDA n.d.). The FDA's 5-20 rule basically instructs the user not to choose a product that in one serving contains more than 5% of the daily value of a nutrient (e.g., sugar) that the user would like to avoid or minimize its consumption. Similarly, it encourages the user to choose a product that contains more than 20% of the daily value in one serving for a nutrient that the user wants to increase its consumption (e.g., protein). The app uses the FDA's 5-20 rule to create thumbs up and thumbs down feedback for desired and undesired nutrients based on user preferences.

Research Question

Our exploratory study was set out to examine the relationship between the variables cognitive effort, usability, and intention to use, shown in Figure 1. As mentioned before, prior studies suggest that cognitive effort may impact usability, and usability may impact behavioral intention. We were also interested to see if the impact of cognitive effort on the intention to use was direct, or it was moderated by usability (Figure 1).

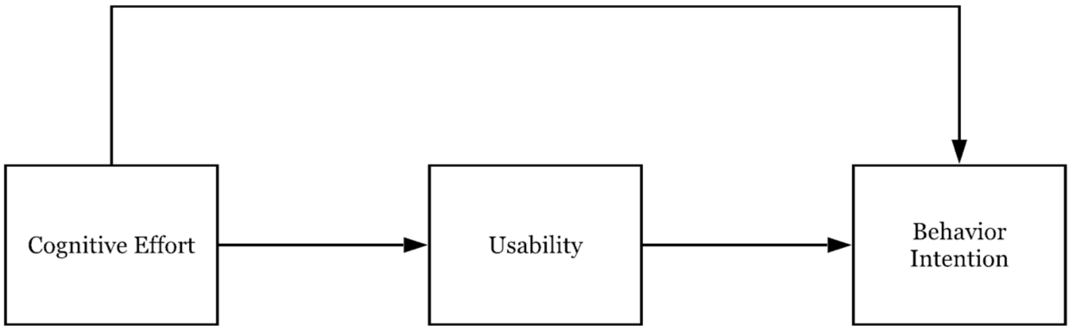

Figure 1. The Proposed Model to Examine the Relationship Between Cognitive Effort, Usability, and Behavior Intention

Methodology

Study participants were recruited from a pool of university students. Each participant completed two decision tasks in random order. Each task required participants to choose the healthiest option (low in sugar and fat; high in protein) among a set of products. Each set contained four similar but anonymous food products with varying nutritional information. For example, one product in the set contained all nutrients in a healthy amount, one contained only one nutrient in a healthy amount, one contained two nutrients in a healthy amount, and one contained all nutrients in an unhealthy amount. The healthy or unhealthy nutrient amount was determined using FDA's 5-20 rule based on 2000 calorie diet (FDA n.d.).

We used Latin Square to assign participants to a mixed experimental design: 1) the repeated measure design to compare the effect of app vs. no app (control), 2) the between-subjects design to compare the impact of two feedback types (pop-up vs. pop-up with audio) on decision performance, perceived cognitive effort, perceived usability, and intention to use the app. To minimize the possibility of the learning effect, we designed the set of products in each task to be different. While all participants completed two tasks (repeated measure design), half completed the first task without the app and the other half with the app. The second task in each group complemented the first task. That is, the no app group, completed the second task with the app, and the app group completed the second task without the app. The app group was further divided into two treatments (between-subjects design): 1) Pop-up, 2) Pop-up with audio groups. Participants were randomly assigned (Latin Square) to either the pop-up or pop-up with audio groups.

We focused on three nutrients in this experiment: saturated fat, sugar, and protein. Saturated fat and sugar can have an adverse effect on health when consumed in large amounts, and protein is essential for weight management (Westerterp-Plantenga, Lejeune, Nijs, Ooijen, and Kovacs 2004; Johnston, Tjonn, and Swan 2004; Drewnowski 2007; Tran and Westbrook 2015). Participants were required to complete the decision-making task based on a scenario. The scenario required them to assume that they recently decided to start eating healthier by reducing saturated fat and sugar and trying to get more protein in their diet. They were also required to assume that as part of their healthy eating habit, they decided to limit their daily calorie intake to 2000 calories. Given this scenario, the participant's task was to select the healthiest product to consume in the set of four food products. They complete one task with the app and another without the app to choose the healthiest product. The experimenter was observing the mobile device during the tasks to note the proper scanning of the label. For pop-up with audio treatment group, the audio output of Bose AR glasses was checked each time before participants performed the task with the device.

We also conducted pre and post tasks interviews. Before starting the task, we ask participants to tell us about their use of nutrition facts label and consciousness about labels (Shah and Hall-Phillips 2018). After completion of each task, participants rated their decision-making process in terms of cognitive effort, usability, and behavior intention. At the end of the experiment, when both tasks were completed, we asked participants some open-ended questions regarding their experience with the app and no app task condition. We also collected demographic information (age and gender) at this time. To measure perceived cognitive effort and behavior intention, we used scales from previous research, which have been validated in prior studies (Hong and Tam 2006, Wang and Benbasat 2009). For usability, we used the System Usability Score questionnaire (Brooke 1996).

Results

Thirty students from a university in the Northeast United States participated in the study, with an average age of 23 years. Participants include fourteen females, fourteen males, and one non-binary/third gender. One participant didn't disclose the gender. In the pre-task survey, participants reported high consciousness towards nutrition facts labels (average score of 4 on a 5-point Likert scale). They use the nutrition facts label while buying food products 'about half of the time' on average (average score of 3.13 on a 5-point Likert scale). On average, they find it 'important' to check the nutrition facts label (average score of 3.27 on a 5-point Likert scale).

Without the app, only 50% of participants were able to make the healthiest selection, while 97% of participants who used the app made the healthiest selection. Table 1 and Table 2 shows paired t-test results between different task conditions. For both feedbacks, participants experienced a significant reduction in the cognitive effort for decision-making tasks when they used the app. They also rated the usability of the app in making healthy food decisions (compared to making decisions without the app using only the information available on the nutrition facts label) significantly better. While the behavior intention was rated slightly more favorably for the app compared to the label, the difference was not significant. The two-sample t-test between the two app feedback designs (pop-up and pop-up with audio) showed no significant difference in cognitive effort, usability, and behavior intention (Table 1).

Experimental Conditions	Pop-up		Pop-up with audio		Two Sample t-test		
	Mean	**SD**	**Mean**	**SD**	**t-stat**	**df**	**p-value**
Cognitive Effort	1.76	0.86	1.84	0.84	2.89	28	0.78
Usability	4.13	0.26	4.13	0.46	0.00	28	1.00
Behavior Intention	3.80	0.99	3.76	0.99	0.14	26	0.89

Table 1. Two Sample T-test Results Between Pop-up and Pop-up with Audio

Paired t-tests comparing cognitive effort, usability, and behavior intention between control condition (decision making without the app by paying attention to the nutrition fact labels) and experimental conditions (decision making with the app using one of the two feedback designs) showed significant difference between control and experimental conditions for cognitive effort and usability but not for intention to use (See Table 2 and 3). The non-significant difference in behavioral intention could be because the feedback was designed to be used with labels. Hence, the intention to use the app was dependent on paying attention to nutrition fact labels.

Experimental Conditions	No App (Control)		App (Pop-up with Audio Feedback)		Paired t-test		
	Mean	**SD**	**Mean**	**SD**	**t-stat**	**df**	**p-value**
Cognitive Effort	3.20	1.07	1.84	0.84	3.50	14	**0.00**
Usability	3.36	0.73	4.13	0.46	3.82	14	**0.00**
Behavior Intention	3.69	0.81	3.76	0.99	0.20	14	0.85

Table 2. Paired T-test Results Between No App (Control) and App (Pop-up with Audio)

To test our proposed model, we used the regression analysis. Table 4 shows the regression results for the no app (control) task condition. Results show that cognitive effort significantly influenced the usability of the label (p=0.00). The usability of the label, in turn, had a significant influence on the behavior intention of using the label (p=0.00). The regression model showed no significant effect of cognitive effort on behavior intention directly. Therefore, the cognitive effort influenced behavior intention through the mediation of the usability, shown in Figure 2.

Experimental Conditions	No App (Control)		App (Pop-up Feedback)		Paired t-test		
	Mean	**SD**	**Mean**	**SD**	**t-stat**	**df**	**p-value**
Cognitive Effort	3.80	0.87	1.76	0.86	4.91	14	**0.00**
Usability	2.89	0.48	4.13	0.26	6.15	14	**0.00**
Behavior Intention	3.38	0.95	3.80	0.74	1.36	14	0.19

Table 3. Paired T-test Results Between Control (No App) and App (Pop-up)

Dependent Variable	Independent Variable	Parameter Estimate	Standard Error	Standardized Coefficient	t-value	p-value
Usability	Intercept	4.69	0.40		11.85	0.00
	Cognitive Effort			-0.62	4.12	**0.00**
	Overall model $R^2 = 0.38$					
Behavior Intention	Intercept	0.86	0.51		1.70	0.10
	Usability			0.71	5.39	**0.00**
	Overall model $R^2 = 0.51$					
Behavior Intention	Intercept	4.54	0.57		7.98	0.00
	Cognitive Effort			-0.33	1.83	0.08
	Overall model $R^2 = 0.11$					

Table 4. Regression Results for No App (Control)

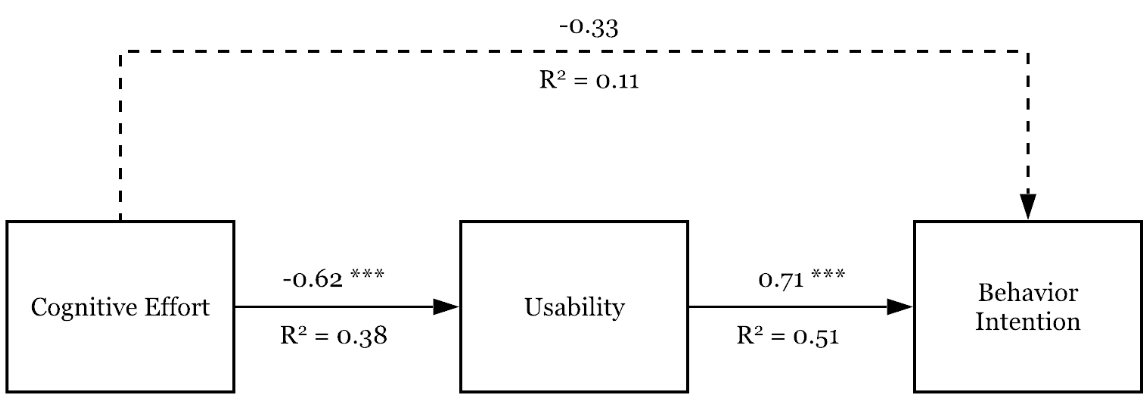

Figure 2. Regression Model for No App (Control)

Table 5 shows the regression results for the pop-up feedback task condition. Results show that cognitive effort had no significant influence over usability. However, usability had a significant influence over behavior intention (p=0.04). The cognitive effort also had a significant effect on behavior intention (p=0.04). Therefore, usability was no longer mediating the influence of cognitive effort on behavior intention, but cognitive effort and usability both were directly affecting behavior intention, as shown in Figure 3.

Dependent Variable	Independent Variable	Parameter Estimate	Standard Error	Standardized Coefficient	t-value	p-value
Usability	Intercept	4.25	0.32		13.30	0.00
	Cognitive Effort			-0.12	0.42	0.68
	Overall model $R^2 = 0.01$					
Behavior Intention	Intercept	0.59	1.41		0.42	0.68
	Usability			0.54	2.29	**0.04**
	Overall model $R^2 = 0.29$					
Behavior Intention	Intercept	4.61	0.40		11.65	0.00
	Cognitive Effort			-0.53	2.25	**0.04**
	Overall model $R^2 = 0.28$					

Table 5. Regression Results for Pop-up Feedback

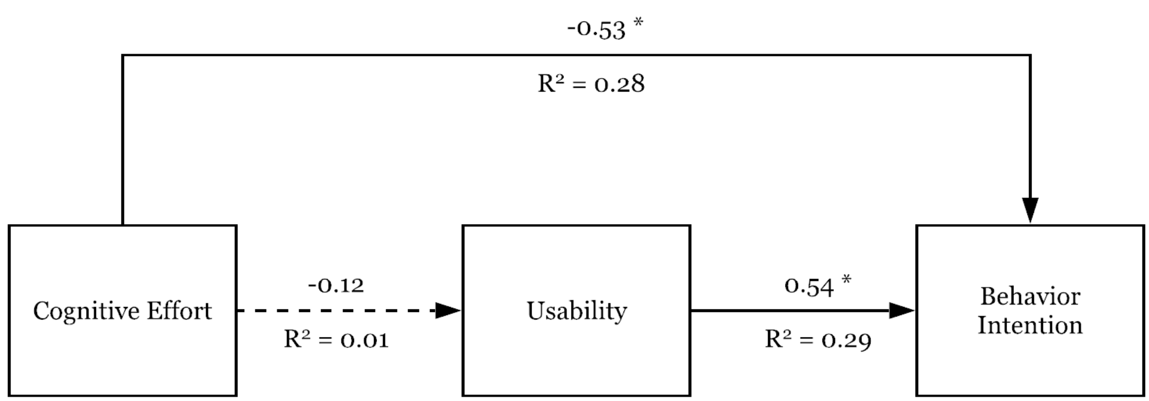

Figure 3. Regression Model for Pop-up Feedback

Table 6 shows the regression results for the pop-up with audio feedback task condition. Results show that cognitive effort had no influence over usability, and usability had no influence over behavior intention. However, the cognitive effort had a significant influence over behavior intention (p=0.02). In other words, usability was no longer mediating the effect of cognitive effort on behavior intention here as well. In this case, usability did not have an impact on intention to use; the cognitive effort was directly affecting behavior intention (Figure 4).

The post-task interviews revealed that participants liked color-coded thumbs up and thumbs down icons, and made their decisions based on them. They found the app feedbacks clear and intuitive. While some participants reported that audio feedback helped relay the information from the app, few mentioned that it was unnecessary. For most participants, the use of nutrition facts label to make the decision was frustrating, time-consuming, and required a lot of calculations. Some participants also pointed out that information in the app feedback provided a limited summary of desired information (about sugar, fat and, protein), whereas nutrition facts labels were far more information dense.

Dependent Variable	Independent Variable	Parameter Estimate	Standard Error	Standardized Coefficient	t-value	p-value
Usability	Intercept	4.32	0.30		14.42	0.00
	Cognitive Effort			-0.18	0.67	0.52
	Overall model $R^2 = 0.03$					
Behavior Intention	Intercept	0.09	2.26		0.04	0.97
	Usability			0.41	1.63	0.13
	Overall model $R^2 = 0.17$					
Behavior Intention	Intercept	5.01	0.53		9.42	0.00
	Cognitive Effort			-0.58	2.58	**0.02**
	Overall model $R^2 = 0.34$					

Table 6. Regression Results for Pop-up with Audio Feedback

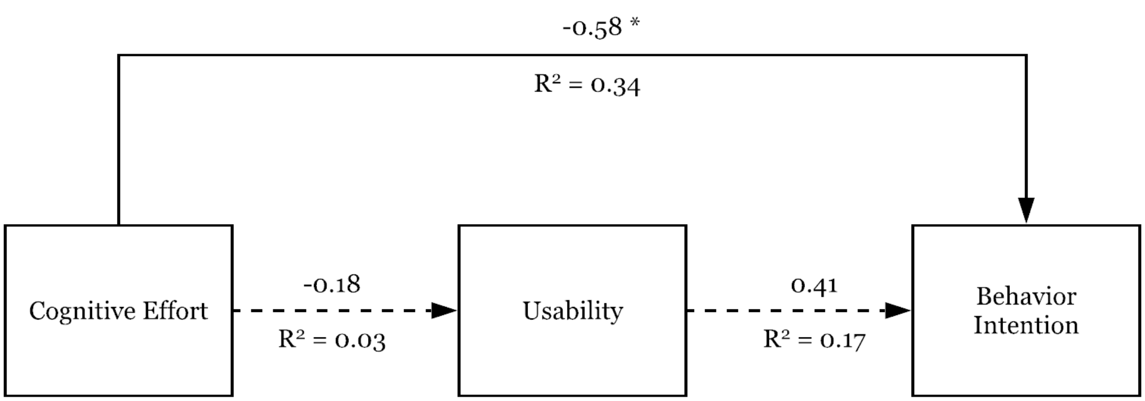

Figure 4. Regression Model for Pop-up with Audio Feedback

Discussion

The results provided evidence that nutrition facts labels were perceived as significantly less usable and required significantly more cognitive effort in decision making. As only 50% of participants were able to select the healthiest product using the label, users were more prone to make errors while using the label for decision making. The use of the label was also reported as frustrating and time-consuming. The app feedbacks helped users in making better decisions by significantly reducing cognitive effort and increasing usability. By enabling 97% of participants to make the healthiest selection, the app feedbacks outperform decision making without the app using only nutrition facts labels. However, the difference in behavioral intention was not significant between the control (no app) and the app (pop-up and pop-up with audio) groups. These could be because participants in our study reported a high level of consciousness towards the nutrition facts label. Because the app scanned the labels, they may have considered the app's feedback as part of using the nutrition fact label. Future studies are needed to explore this possibility.

The regression model for the control (no app) in Figure 2 shows that the impact of cognitive effort on behavioral intention was mediated by usability. However, this mediation no longer existed in the regression model for the pop-up feedback of the app, shown in Figure 3. The cognitive effort had no significant effect on usability; it had a significant direct influence on behavior intention. This change could be because the use of pop-up significantly improved usability (as shown by the results in table 2) and hence eliminated usability as a mediator in the model. In the regression model for pop-up with audio feedback shown in Figure 4, the effect of usability becomes non-significant on behavior intention. The cognitive effort was directly and significantly influenced behavior intention in this case. There was no mediation, as well. This could be due to the addition of audio AR, which improved the usability of the feedback and hence rendered usability of the feedback not to have a significant role in the model.

Limitations and Future Research

Although the results of app feedbacks show a significant reduction in cognitive effort and a significant increase in usability, more data is required for the generalizability of the results. Our subjects were all university students. They were generally younger users, tech-savvy, and reported high consciousness about nutrition facts label. These factors could have influenced our results. In the future, the same model should be evaluated with a broader population of users, e.g., with different age groups, backgrounds, and consciousness towards nutrition facts labels. The study was conducted in a laboratory setting. Future field studies can improve the generalizability of the results. We used only three factors (sugar, fat, and protein) in this study, including more factors can yield different results. The small sample size is also one of the limitations of the study, we will address this limitation in our follow-up research.

This exploratory study tried to identify the relationship between cognitive effort, usability, and behavior intention using two feedback designs. Our results indicate that when the cognitive effort is high, and usability is low (no app condition), the cognitive effort has an impact on behavior intention through the significant mediation of usability. As cognitive effort goes down and usability improves, the role that usability plays in the model becomes less nuanced.

REFERENCES

Bose. Retrieved February, 27, 2020, from https://www.bose.com/en_us/better_with_bose/augmented_reality.html

Brooke, J. 1996. "Sus: A 'Quick and Dirty' Usability Scale," in *Usability Evaluation in Induatry,* P.W. Jordan, B. Thomas, B.A. Weerdmeester and I.L. McClelland (eds.). pp. 189-194.

Bullard, G. 2019. "Now Hear This: Augmented Reality Comes to Audio." Retrieved February 27, 2020, from https://niemanreports.org/articles/now-hear-this-augmented-reality-comes-to-audio/

Chapanis, A. 1964. "Knowledge of Performance as an Incentive in Repetitive, Monotonous Tasks," *Journal of Applied Psychology* (48:4), pp. 263-267.

Cowburn, G., and Stockley, L. 2005. "Consumer Understanding and Use of Nutrition Labelling: A Systematic Review," *Public Health Nutrition* (8:1), pp. 21-28.

Davis, F. D., Bagozzi, R. P., and Warshaw, P. R. 1989. "User Acceptance of Computer Technology: A Comparison of Two Theoretical Models," *Management Science* (35:8), pp. 982-1003.

Djamasbi, S., Li, W., Traietti, M., Tran, L. C. T., Valcour, V., Wyatt, J., and Yuan, F. 2015. "Web Experience and Growth," in: *Americas Conference on Information Systems 2015*.

Drewnowski, A. 2007. "The Real Contribution of Added Sugars and Fats to Obesity," *Epidemiologic Reviews* (29:1), pp. 160-171.

FDA. "How to Understand and Use the Nutrition Facts Label." Retrieved February, 27, 2020, from https://www.fda.gov/food/nutrition-education-resources-materials/how-understand-and-use-nutrition-facts-label

Holden, H., and Rada, R. 2011. "Understanding the Influence of Perceived Usability and Technology Self-Efficacy on Teachers' Technology Acceptance," *Journal of Research on Technology in Education* (43:4), pp. 343-367.

Hong, S.-J., and Tam, K. Y. 2006. "Understanding the Adoption of Multipurpose Information Appliances: The Case of Mobile Data Services," *Information Systems Research* (17:2), pp. 162-179.

Jacoby, J., Mazursky, D., Troutman, T., and Kuss, A. 1984. "When Feedback Is Ignored: Disutility of Outcome Feedback," *Journal of Applied Psychology* (69:3), p. 531.

Jain, P., and Djamasbi, S. 2019. "Using Audio Augmented Reality to Support Decision Making," *Eighteenth Annual Workshop on HCI Research in MIS, ICIS 2019*, Munich, Germany.

Johnston, C. S., Tjonn, S. L., and Swan, P. D. 2004. "High-Protein, Low-Fat Diets Are Effective for Weight Loss and Favorably Alter Biomarkers in Healthy Adults," *The Journal of Nutrition* (134:3), pp. 586-591.

Nguyen, H., Ruiz, C., Wilson, V., Strong, D., and Djamasbi, S. 2018. "Using Personality Traits and Chronotype to Support Personalization and Feedback in a Sleep Health Behavior Change Support System," *Proceedings of the 51st Hawaii International Conference on System Sciences*.

Shah, P., and Hall-Phillips, A. 2018. "Antecedents and Implications of Expiration Date Search Effort," *Journal of Consumer Affairs* (52:2), pp. 229-251.

Stewart, J. 2019. "Audio Augmented Reality Is About to Make Headphones a Lot Smarter." Retrieved February 27, 2020, from https://www.marketplace.org/2019/06/17/audio-augmented-reality-is-about-make-headphones-a-lot-smarter/

Te'eni, D. 1991. "Feedback in Dss as a Source of Control: Experiments with the Timing of Feedback," *Decision Sciences* (22:3), pp. 644-655.

Temple, N. J., and Fraser, J. 2014. "Food Labels: A Critical Assessment," *Nutrition* (30:3), pp. 257-260.

Torning, K., and Oinas-Kukkonen, H. 2009. "Persuasive System Design: State of the Art and Future Directions," in: *Proceedings of the 4th International Conference on Persuasive Technology*. Claremont, California, USA: Association for Computing Machinery, p. Article 30.

Tran, D. M., and Westbrook, R. F. 2015. "Rats Fed a Diet Rich in Fats and Sugars Are Impaired in the Use of Spatial Geometry," *Psychological science* (26:12), pp. 1947-1957.

Wang, W., and Benbasat, I. 2009. "Interactive Decision Aids for Consumer Decision Making in E-Commerce: The Influence of Perceived Strategy Restrictiveness," *MIS Quarterly* (33:2), pp. 293-320.

Westerterp-Plantenga, M. S., Lejeune, M. P. G. M., Nijs, I., van Ooijen, M., and Kovacs, E. M. R. 2004. "High Protein Intake Sustains Weight Maintenance after Body Weight Loss in Humans," *International Journal of Obesity* (28:1), pp. 57-64.