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Examining user perceptions of smartwatch through dynamic topic modeling

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ABSTRACT

Since the 2010s, various companies have begun to manufacture wearable smartwatch devices, but the current sales of these products are not impressive. This study investigates how the limitations of the smartwatch are related to perceptual discomforts. Theoretically, this study evaluates the claim that the discomfort that users appear to have with the smartwatch stem from failed remediation. Users perceive the smartwatch more as a set of functional sensors rather than a watch or smartphone. Specifically, from the remediation perspective, the authors asked how users perceive the functions of the smartwatch. This study used dynamic topic modeling for topics on the smartwatch on Reddit. This study reports that the smartwatch has failed to provide a proper way to use the remediated content that it provides. Suggestions for future studies are addressed.

1. Introduction

The 21st century appears to be the dawn of the age of 'smartness' with the introduction of the smartphone, smart notebook, smart TV, and even the smart washing machine. But what makes all these products 'smarter' than their forerunners? According to the Gartner IT Glossary, smart technologies "learn on their own and can produce unanticipated results" (Gartner, 2016). The way that these devices are able to learn is based on how they adapt their behavior from the interactions that they have had with the user.

One of these smart devices is the smartwatch. From the 2010s, the smartwatch became known as an effectively wearable computer that can help its users create a more convenient way of keeping track of the notifications that they receive. At the same time, the smartwatch consists of a heart rate sensor, a built-in GPS (Global Positioning System), and AI (Artificial Intelligence) software that allows the user to get feedback on their body state anywhere and anytime. The smartwatch can wirelessly connect to other smart devices, so that notifications and body analyses can be sent to other smart devices the user owns. This synchronization of data from various gadgets thus leads to a database and a network of data of the user; data from which the smartwatch can learn and produce unanticipated results.

Lots of different companies including Pebble, Samsung, and Apple have produced their own lines of smartwatches. Smartwatches synchronize their data with other devices. For example, the Apple Watch can synchronize data with the iPad, iPhone, Mac, and Apple TV. Although a lot of companies went with the flow of producing smartwatches, the sales for most companies failed to reach their expectations. As of the third quarter of 2016, the whole smartwatch market has declined 51.6% in its year-over-year growth (IDC, 2016). The predicted success, that the worldwide annual shipments of

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smartwatches would be 80 million at the end of 2016, has turned out to be incorrect (Siegal, 2013). It is therefore quite questionable if the forecast of 373 million annual sold smartwatches will be reached in 2020 (Siegal, 2013).

Several studies have investigated the factors that influence the intention to use smartwatches. For example, Choi and Kim (2016), Kim and Shin (2015), and Wu et al. (2016) showed perceived self-expressiveness, cost, and perceived social influence significantly affect the intention to use respectively. Partially, Choi and Kim (2016) and Kim and Shin (2015) showed perceived usefulness significantly exerts influence on attitudes toward using smartwatches. Choi and Kim (2016) and Wu et al. (2016) reported perceived enjoyment significantly affects attitude toward using smartwatches. However, some findings of these studies are unclear or conflict with each other. For instance, in Kim and Shin (2015), perceived ease of use was observed as a significant factor for attitudes toward using smartwatches but in Choi and Kim (2016) and Wu et al. (2016) it was not a significant factor. The smartwatch is required to be a luxury item but also to be practical (Cecchinato et al., 2015; Choi and Kim, 2016). However, inconsistent reports from the studies often make it difficult for designers to understand users' needs for smartwatches.

Thus, a more theoretical approach is required to understand the smartwatch. Users' judgments on the use of the smartwatch cannot be analyzed without comprehensive understanding of the perception of the smartwatch. The functional relationships among the smartwatch, watch, and smartphone are not easily described by a simple questionnaire term such as compatibility or relative advantage. Rather, this problem should be investigated based on the analysis of how the users perceive the smartwatch and its functions. In this study, user comments for smartwatch usage are gathered from Reddit and significant topics in the comments are captured by dynamic topic modeling. Through these processes, this study examines (1) how user perception on the smartwatch can be understood from the remediation perspective; (2) how smartwatch usage can be understood from the enactive cognition perspective; and (3) how the functions of the smartwatch can be understood from the distributed cognition perspective. Subsequently, this study also discusses the limitations of the current smartwatch and suggests future directions.

2. Remediation

Remediation theory enables us to describe the smartwatch with regard to two traditional media, the watch and smartphone, and to understand the gap between the functional properties of smartwatches and users' perception of them. The concept of remediation was first suggested by Bolter and Grusin (2000) based on the ideas of McLuhan (1964). According to Bolter and Grusin, two remediation strategies, immediacy and hypermediacy, can be traced back to the Renaissance, and they can still be found in the digital age. Immediacy is a form of remediation in which the medium "erases itself, so that the user is no longer aware of confronting a medium, but instead stands in an immediate relationship to the contents of that medium" (Bolter and Grusin, 2000, p. 24). In the Renaissance, immediacy can be found in the way painters started to paint in perspective; images were no longer two-dimensional, but the painting portrayed a different world which the spectator could easily 'step into'. A contemporary example of immediacy is the way that Virtual Reality (VR), as produced by the Oculus Rift, invites the user to step into a world that appears to be as real as the outside world. In this way, both the perspective painting and VR are remediating the experience of perceiving the world; they are different communication tools with the same message, and their form transmits a feeling of transparency to the user.

The second form of remediation that Bolter and Grusin describe is hypermediacy. In contrast to immediacy, hypermediacy "offers a heterogeneous space, in which representation is conceived of not as a window on to the world, but rather as 'windowed' itself [...] [it] multiplies the signs of mediation and in this way tries to reproduce the rich sensorium of human experience" (Bolter and Grusin, 2000, p. 34). Although immediacy was the dominant form of remediation during the Renaissance, from the Industrial Revolution onwards, hypermediacy became a common form of remediation that can be traced back to the creation of, like Bolter and Grusin suggest, the diorama, the phenakistoscope, and the stereoscope. A present-day example of hypermediacy is the point-of-view perspective that Internet users can use in Google Maps: you see the streets on the map from the perspective of a pedestrian on the street, although it still creates the awareness that you are looking at a map. Various forms of Augmented Reality (AR) are also good examples in which remediation occurs in a bricolage form, as is natural for hypermediacy.

From the remediation perspective, the failure of the smartwatch is due to the gap between the functions of smartwatches and users' perception of them. The smartwatch remediates two media. The first one is the ordinary watch (as it states in the name). Its content, telling time, is remediated in the new device. The second medium is the smartphone. The smartwatch providers have created software on the smartwatch in which the user can see notifications, respond to messages, and answer calls. The remediation of these media is structured in an immediacy fashion, although the consumer's perception of the smartwatch can be considered as hypermediacy: the user is invited to stand in an immediate relationship with the contents of that smartwatch, while the user perceives the device as multiplying the signs of mediation through the availability of many options. This perceptual gap may hinder the intention to use or buy a smartwatch.

3. Enactive cognition

Enactive cognition theory provides a useful frame to understand how users build their cognitive structure for a device and why smartwatch users have a flawed user experience. Varela, Thompson, and Rosch (1991) described how human cognition

should "no longer [be] seen as problem solving on the basis of representations; instead, cognition in its most encompassing sense consists in the enactment or bringing forth of a world by a viable history of structural coupling" (Varela, Thompson, & Rosch, 1991, p. 205). This is what the authors call *enactive cognition*: cognition is the creation of a sensible world through action. The enactive approach consists of two points (Varela et al., 1991, p. 173). First, perception consists of perceptually guided actions. Perception is thus not the making of an observation, but is the perceptual act that makes you observe something; the guidance of action in and by the body. Second, cognitive structures emerge from the recurrent sensorimotor patterns that enable action to be perceptually guided.

In the case of smartphones, the act of swiping with one's finger to the left or to the right results in moving to a new home screen. The body receives feedback from the interaction with the phone. When the body repeats this meaningful interaction sensorimotor act of swiping, this perceptual act creates a cognitive structure for the body. This example thus shows that cognition is not something that is solely placed in the brain, rather it is embodied. At the same time, it shows that cognition is enactive, since the ability to make sense of the environment lies in the act of perception itself. The way to make sense of the environment though the enactive approach can also be applied to the smartwatch. When users wear a smartwatch, they make sense of the device by using it. For example, when a user perceives a notification on their smartwatch, the user's pair of eyes need to look at the screen positioned on their wrist. To get an optimal observation, the wrist must be put in the right angle in accordance with the head. Before users head on to addressing their reaction to the notification, it must be considered that this act of perception is already different from the medium that the smartwatch is trying to remediate: the smartphone. Users have trained their body in the last couple of years in how to properly react to smartphone notifications. However, when another device attempts to remediate this medium, users assume that their manner of perception is not remediated. This problem is a reason for users' hesitations to use smartwatches.

4. Distributed cognition

Distributed cognition theory helps to understand the interaction between the user and smartwatch. Distributed cognition claims that one's cognition is not expressed by a sole individual agent but done with cognitive cues distributed to the environment (Hutchins, 1995). In understanding how distributed cognition exactly works, Zhang and Norman (1994) formulated three key principles that constitute this type of cognition. First, the embodiment of information can be found in representations of interaction. Second, there is coordination of enaction among embodied agents. Finally, the distributed cognition contributes ecologically to a cognitive ecosystem. The smartwatch is a device that can be considered as a machine with distributed cognition: it can interpret information (like your heartbeat), and it can generate a meaningful message from that information. The smartwatch needs to be connected to a smartphone, and it is often also connected to other smart devices, like a tablet or a notebook. However, it fully depends on a smartphone to receive valuable data.

5. Research questions

Given the discussions above, the smartwatch is a device that remediates the smartphone with the technique of immediacy: it tries to establish an immediate relationship between the remediated content and the user through transparency. However, the remediation is perceived by the user in a manner of hypermediacy: the user is invited to communicate like one does on a smartphone, with the availability of the many options that the device has to offer. Also, the smartwatch presents a new mode of enactive cognition and distributed cognition.

Research questions in this research are:

RQ1. How are remediation, enactive cognition, and distributed cognition related to the perception of the smartwatch as observed on Reddit?

RQ2. How can the smartwatch be improved considering the findings from RQ1?

6. Method

To solve the research questions, this study collected user opinion data from a website, *Reddit*, and analyzed it in two ways. First, the authors distinguished significant topics and trends based on the dynamic topic modeling technique. Second, the authors focused on high scored posts and comments and examined what they suggest for the usage of smartwatches. Then, the authors discussed findings in terms of the theoretical perspectives in the previous section. Fig. 1 shows the overall procedure of the analysis.

6.1. Data collection

User opinions on the smartwatch were collected from the website Reddit (http://www.reddit.com). Reddit is a website where users actively share their opinions on various topics. When a user addresses a topic with a post, users can discuss the topic by commenting on the post. Also, users can express their agreements with a post by up/down voting the comments. This study collected all posts and comments in a subcategory of Reddit (*subreddit*) to observe the user opinions on the smartwatch.

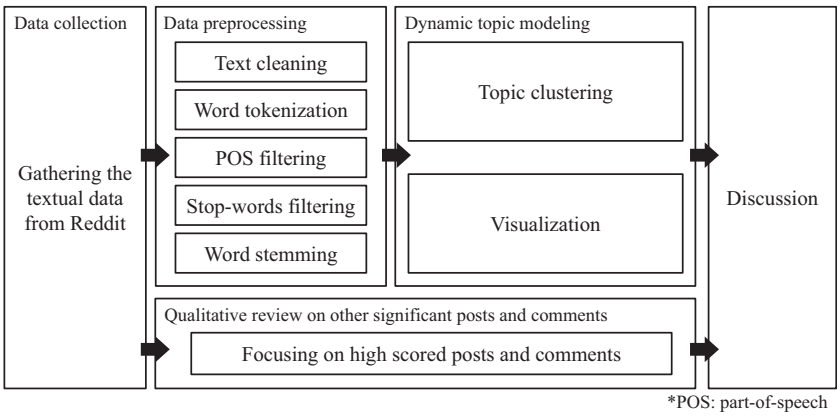

Fig. 1. Overall procedure of analysis.

6.2. Data preprocessing

As a preprocessing part of the analysis, this study refined the raw textual data with several steps. First, the textual data was cleansed with two processes: typographical errors in text were corrected, and variations of product names were standardized into one (text cleaning). Then, the cleansed text was tokenized into a bag of words (word tokenization). After the tokenization process, the POS (part-of-speech) of each word in a sentence was tagged. Considering the research of Mihalcea and Tarau (2004), only nouns and adjectives were used to produce accurate results for the analysis (POS filtering). Next, punctuation and stop-words in the POS filtered words were removed (stop-words filtering). At the final step, the words were stemmed with a snowball algorithm and variations of the words were standardized into one (Porter, 2001) (word stemming).

6.3. Dynamic topic modeling

Dynamic topic models are generative models which enable the identification of topic evolution over time (Gerrish and Blei, 2010). Several researchers have utilized the dynamic topic models to investigate user opinions in online communities (Cao and Tang, 2014; Parra et al., 2016). In the dynamic topic model, each document is assumed to have several topics and words that follow a multinomial distribution. Parameters of the model are inferred through the variational method applying the variational Kalman Filtering and the variational wavelet regression. Gensim (https://radimrehurek.com/gensim) and NLTK (http://www.nltk.org), python libraries for natural language processing were used to apply the dynamic topic modeling technique to this study. The authors monitored ten topics each month and discussed meaningful issues related to them.

6.4. Qualitative review on other significant posts and comments

Dynamic topic modeling automatically enables the identification of remarkable words with subtle connotations in the data. Once topics are identified through dynamic topic modeling, since omitted parts of a text can also provide significant meanings, the authors manually re-investigated the posts and comments that mentioned significant issues. Through this qualitative review, the authors categorized contents of the posts and comments and discussed meaningful insights from them.

7. Results

7.1. Basic statistics and trend analysis

During the period from June 18, 2015 to November 21, 2016, 4216 posts and comments were collected from the smartwatch topic subreddit. Due to the restrictions of Reddit, the authors were able to access the data from limited dates. Table 1 shows the basic statistics of the data and Fig. 2 describes the patterns for the number of posts and comments chronologically (by day and month). The comment types were described in detail by specifying their levels from c1 to c5: the c1 level comment indicates a comment replying to a post and the c5 level comment indicates a sub-comment replying to the c4 level comments. The data in the first (Jun 2015) and last month (November 2016) are not full-monthly data. Thus, the present study described the properties of these data but did not consider them for the comparison.

Table 1
Basic statistics for the data.

Time	2015–06	2015–07	2015–08	2015–09	2015–10	2015–11	2015–12	2016–01	2016–02
# P&C	121	374	320	386	238	266	322	182	116
S. Mean	1.876	1.912	2.269	1.930	2.097	2.195	2.050	2.231	2.966
S. Std	1.435	1.820	2.375	2.169	2.102	2.311	2.302	2.384	2.859
S. Min	0	−3	−2	−7	−5	−4	−1	0	0
S. Max	7	13	13	22	16	22	26	17	18
Time	2016–03	2016–04	2016–05	2016–06	2016–07	2016–08	2016–09	2016–10	2016–11
# P&C	182	233	282	233	155	183	272	196	155
S. Mean	2.890	2.541	2.323	2.189	2.368	2.148	2.221	2.245	2.161
S. Std	2.964	2.585	2.257	2.082	1.886	1.749	2.177	2.691	1.922
S. Min	−2	−1	−2	−1	0	0	−1	−6	−2
S. Max	14	15	15	14	9	7	16	14	10

Note. # P&C = the number of posts and comments for the period; S. Mean = mean of the scores for the posts and comments; S. Std = standard deviation of the scores for the posts and comments; S. Min = minimum of the scores for the posts and comments; S. Max = maximum of the scores for the posts and comments.

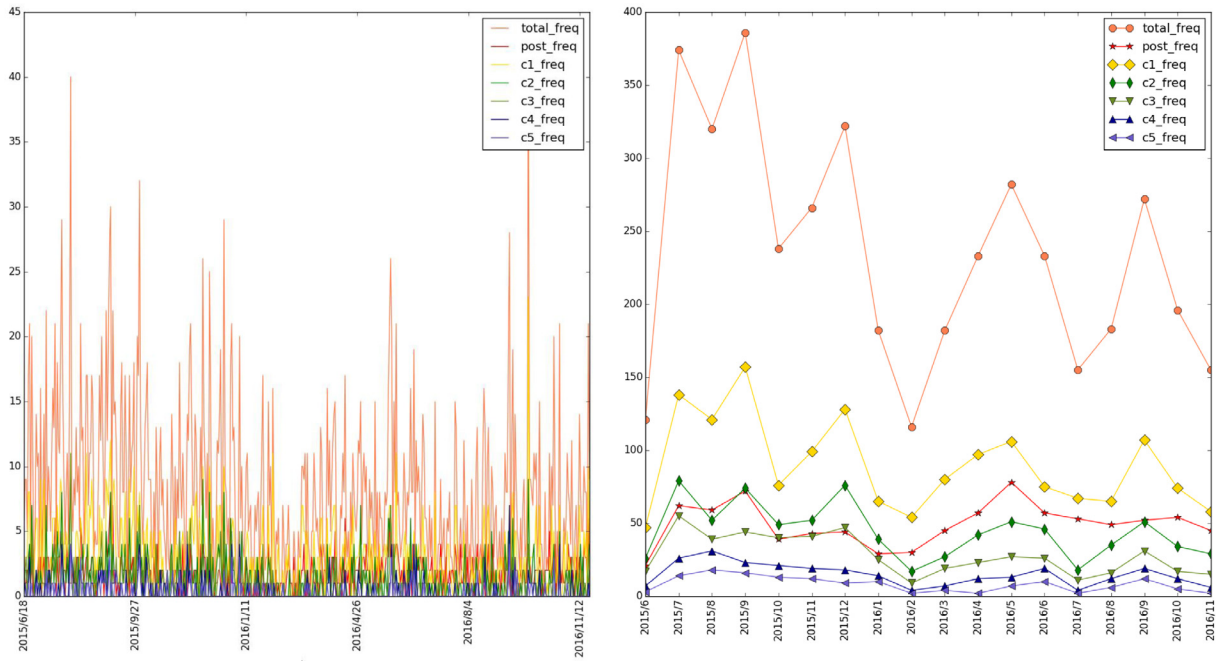

Fig. 2. The number of posts and comments over time (per day on the left; per month on the right).

7.2. Dynamic topic modeling

For the given period, this study observed ten topic threads based on the dynamic topic model (see Table 2). Regarding the research questions, three topic threads were chosen (1, 8, and 9) and their keywords were visualized chronologically. The other topic threads (2–7 and 10) were not investigated in detail because they were focused on news for specific products or just indicated the amount of discussions. Figs. 3–5 show the visualization of these results.

Topic thread – Capability. As for the topic thread 1 (Capability), the authors could observe that many users are interested in some functions of the smartwatch, especially the functions for healthcare and fitness (see Fig. 3). In Fig. 3, the X-axis shows each month; the Y-axis shows word occurrence probability in the topic.

Two keywords related to the healthcare and fitness, "fit (fitness)" and "heart", have appeared since December 2015 and February 2016 and their appearances in the given topic increased steadily. The keyword "pebble" decreased steadily. Possibly, this is because many competitors were released over the course of time. One post shows how a user searches for what smartwatch he or she should buy:

> "*Hey y'all, I'm new here. I'm looking for a fitness tracker. A must have is a heart rate monitor and calorie burn counter, it would also be nice if it was water proof and could be worn on my ankle. It doesn't need to act like a traditional watch, I already have one. [. . .]*"

Table 2
Topic threads in the dynamic topic model.

Topic thread 1 (Capability)	Topic thread 2 (Android vs. iOS)	Topic thread 3 (Competitors 1)	Topic thread 4 (News)	Topic thread 5 (Open questions)
smartwatch	android	lgwatch	news	question
pebbl(e)	smartwatch	smartwatch	thank	free
smartphon(e)	wear	pebblewatch	smartwatch	thread
time	ios	lg	comment	answer
app	smartphon	urban	thread	page
appl(e)	app	moto360	link	welcom(e)
water	music	huawei	open	post
rate	compat	look	today	rule
notif(ication)	iphon(e)	steel	repli(reply)	matter
thing	applewatch	band	wednesday	anyon(e)
fit(ness)	thank	gen	top	smartwatch
heart monitor				end
Topic thread 6 (Innovation)	**Topic thread 7 (Samsung)**	**Topic thread 8 (Battery)**	**Topic thread 9 (Screen & Display)**	**Topic thread 10 (Competitors 2)**
smartwatch	galaxygear	batteri(battery)	smartwatch	smartwatch
smart	samsung	life	price	moto360
first	galaxyphon(e)	smartwatch	screen	zenwatch
anyon(e)	smartphon(e)	day	new	sure
time	app	time	display	thing
face	smartwatch	round	model	thank
someth(ing)	googl(e)	pebbl(e)	pebbl(e)	best
idea	tizen	pebblewatch	good	use
interest	notif(ication)	soni(sony)	better	better
way	new	last	great	peopl(e)
updat(e)	call		review	money
issu(e)				price
				sport
				appl(e)

Note. Some keywords in the table are expressed in a stemmed form (e.g., smartphon = smartphone, notif = notification). Several series product names are unified into one (e.g., galaxy gear, gear2, S, S2, and S3 = galaxygear).

The authors observed that many users tend to look for a smartwatch focusing on the healthcare functions. The users expect the ideal and suitable smartwatch can provide a set of differentiated functions that the traditional watches do not provide. They do not care about the wearable form of the watch and they find various ways to use it (e.g., "it would be nice if it could be worn on my ankle"). This implies that the users regard the smartwatch as a new device which can provide original functions and help find a way to extend the human's body. In this topic thread, the authors were able to observe that the functions particularly focused on healthcare and fitness purposes, and that not only the wrist but also the ankle can be considered for the functional body extension device.

Topic thread – Battery. Regarding the topic thread 8 (Battery), the authors were also able to observe that users care about the battery in the smartwatch (see Fig. 4).

An interesting point was that the probabilities of the keywords "battery", "day", and "life" steadily decreased over time. The battery issue has been criticized as an important problem in the smartwatch and many companies have tried to solve this problem. Fig. 4 implies that the battery problem is perceived as being improved over time by users. One comment shows how a user perceives the battery issue:

"[. . .] But the tradeoff for added/different functionality is battery life. [...] Pebbles have long battery life because they don't have a touchscreen or an LCD/OLED type screen that pulls a lot of battery. [. . .] But the part about best vibration/customization/speech recognition is purely personal opinion. [...] At the end of the day, it's a choice between buttons vs touchscreen, longer battery life vs more functionality, etc."

The authors observed that the users regard the battery issue as a trade-off problem. Many smartwatches require high battery capacity because they have a touch screen, a colorful display, or some artificial intelligent functions. However, some users do not need those specifications and only want some basic functions of the watch. Based on this observation, the authors can infer two reasons why the probabilities of the battery related keywords have steadily decreased: (1) the battery capacity in the smartwatch could have been improved significantly, or (2) the users steadily recognize that the battery problem is actually more related with the number of functions, and several competitive watches with basic functions have started to fulfill the needs of users who do not need the various functions.

Topic thread – Screen & Display. As for the topic thread 9 (Screen & Display), the authors were also able to observe that users care about the screen and battery issues in the smartwatch (see Fig. 5).

The authors named topic thread 9 "Screen & Display" based on the keywords of the topic thread. However, the authors observed that two major keywords, "screen" and "display", showed different patterns over time. The screen keyword showed

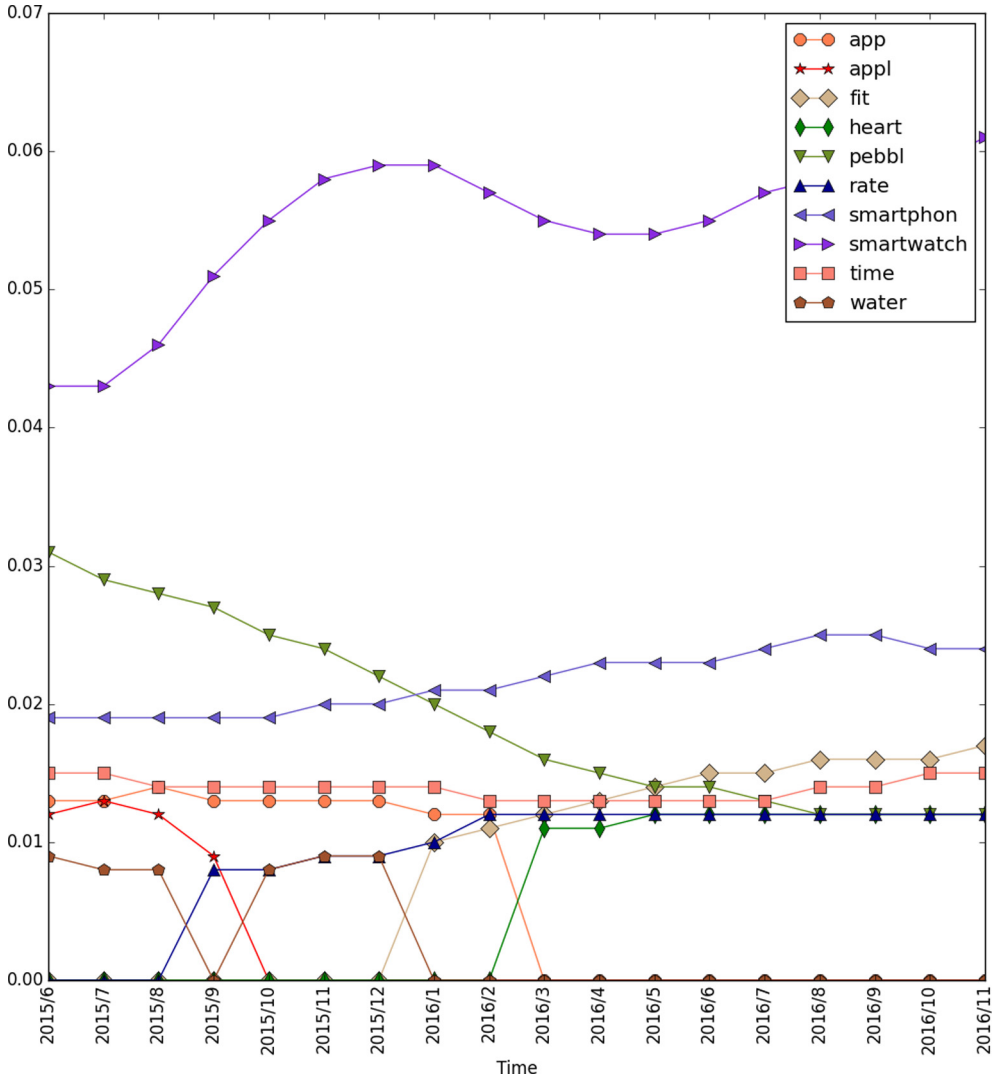

Fig. 3. Visualization for the topic thread 1 (Capability).

an increasing pattern, whereas the display keyword showed a decreasing one (April, 2016). To check the different uses of the keywords, the authors looked into some comments. One comment shows how a user uses the two keywords with different meanings:

> *"[...] I'm eagerly awaiting the new version as well as it will likely have better battery life, a better display (rumored to eliminate the black bar at the bottom of the screen and a higher resolution), and it likely will be thinner. If you still opt for the first gen device, I'd wait until the new one comes out as it will likely drop in price even more by then."*

The authors observed that sometimes the use of the screen keyword was related to a perceptual property, whereas the use of the display keyword was related to a physical property. However, in many cases, users employed the two keywords as synonyms regardless of the differences. Considering the usage of the two keywords, the authors can confirm that the screen and display issue has decreased over time, although the screen keyword has increased a little. However, this does not imply that the screens and displays of smartwatches became similar. A more reasonable interpretation is that the smartwatch market has become segmented over time, therefore users started to mention the names of several smartwatches rather than asking for the screen and display information explicitly. The patterns of other keywords, "price", "new", and "good", support this interpretation. Although the screen and display keywords either increased a little or rapidly decreased, the mentioning of "price", "new", and "good" keywords increased highly. One post shows a common approach when users find the smartwatch they want to buy:

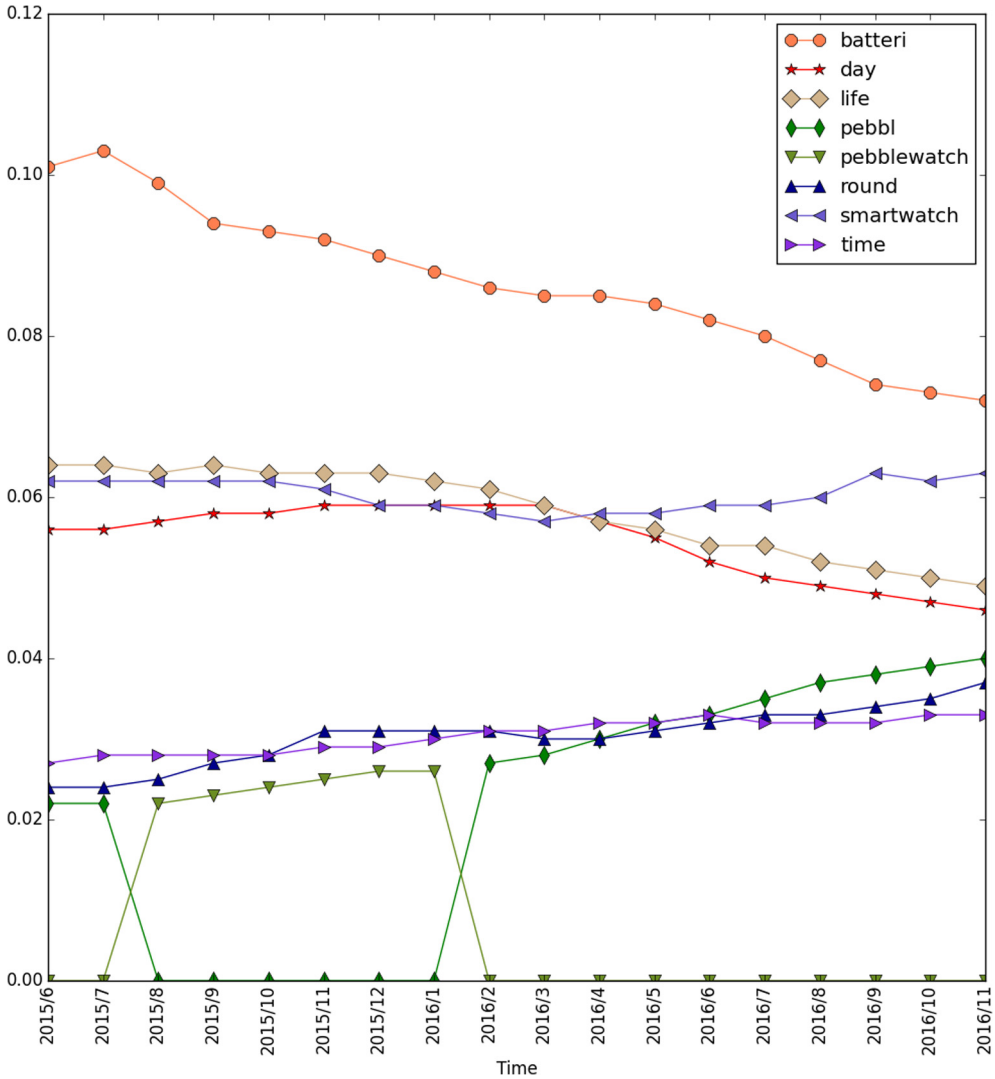

Fig. 4. Visualization for the topic thread 8 (Battery).

"*[. . .] I have an Android (Nexus 5). I do care about price, but would want to see what people suggest first, then narrow it from there. I care little about texting, emailing that sort of thing from it. I've seen some really cheap most likely Chinese smart watches on Amazon, are those good enough? [. . .]*"

The authors also observed the keyword "pebble", the name of a smartwatch company, which was frequently mentioned in the posts and comments. Many products of Pebble are known as simple since they only provide a set of essential functions for the user. In this topic thread, the keyword pebble appeared from December 2015 whereas the mentioning of the display and model keywords disappeared between December 2015 and April 2016. Considering the interpretation above, the authors presume that users' expectations for the display were steadily replaced by Pebble.

7.3. Qualitative review on other significant posts and comments

In this research, the authors used posts and comments that received a high number of vote and were mainly related to news regarding the smartwatch and warnings for certain scams related to the sale of smartwatches. Due to the limitation of length, the authors provide examples retrieved from the qualitative review:

"*Another Kickstarter Scam!! [. . .] I still have not receive the product today, [. . .]*" / "*Hands on with the smartwatch from Google's new investment: Mobvoi [. . .]*" / "*BLOCKS, a modular smartwatch kickstarter.*"

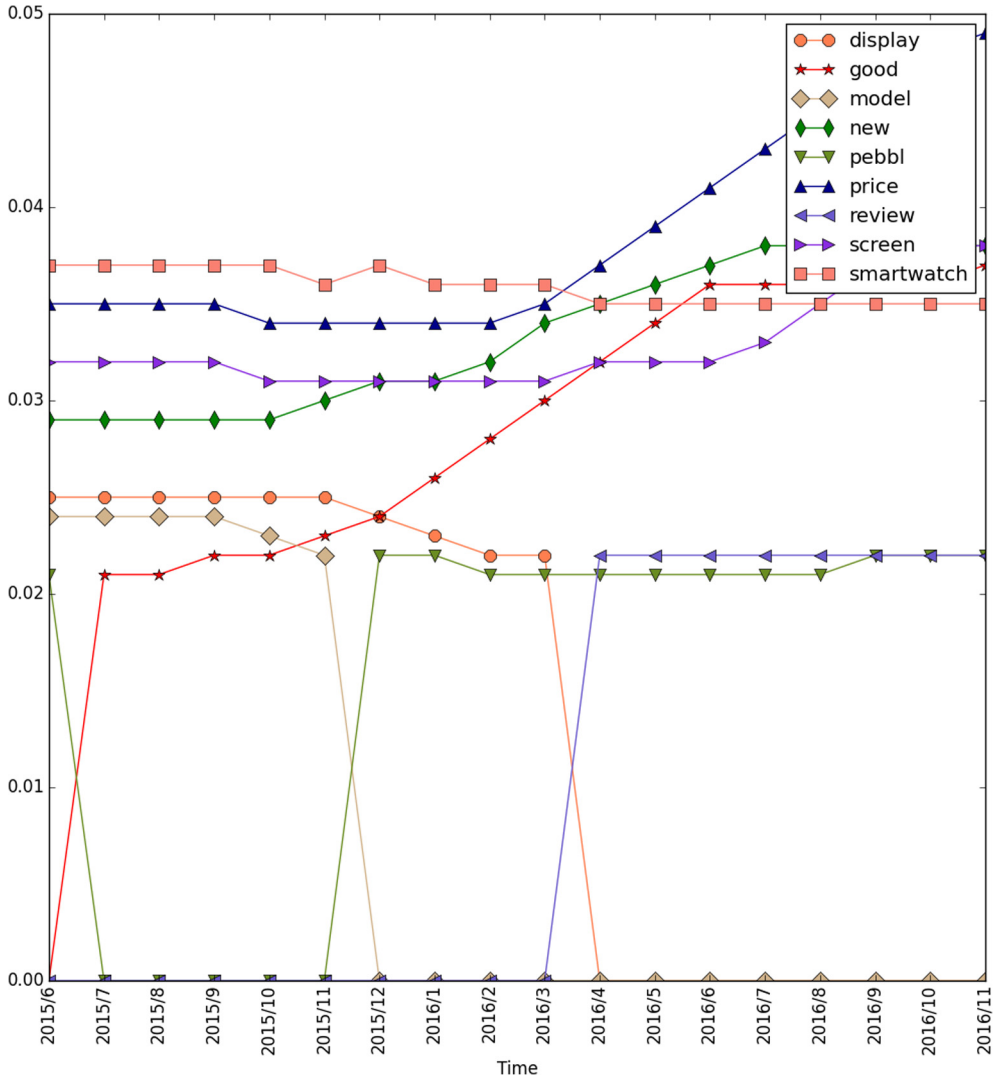

Fig. 5. Visualization for the topic thread 9 (Screen & Display).

Some posts and comments were related to issues regarding smartwatch functions. The following post mentions that some functions of smartwatches (e.g., writing a reply to a message or check the weather) are uncomfortable and hard to differentiate from those in smartphones:

"What do you use your smartwatch for? [...] I already have my phone on my most of the day, and a fitbit flex, along with sHealth for fitness tracking. [...] Since I started carrying a phone, I stopped wearing a watch. Watches seem like a bad way to reply to text messages, so do you simply read them on your watch? Is it really any easier to check the weather on a watch than your phone?"

The following post shows an interesting suggestion for smartwatch development:

"[...] I'd like to say this about smart wearables: STOP MAKING THEM LOOK LIKE LEGACY TECH. A watched was round or square, an inch or two in diameter, for a reason! If you want to increase battery size and life, make the damn thing look like new tech! [...] Is anyone designing a smart watch or wearable that looks like something we haven't seen before?"

This post argues that the current smartwatches are restricted to the traditional watch forms and this kind of approach is unnecessary or even wrong. In other words, this post implies that users tend to perceive the smartwatch as a set of functional sensors rather than a watch; which is already captured by the dynamic topic model analysis (topic thread 1).

8. Discussion

RQ1. How are remediation, enactive cognition, and distributed cognition related to the perception of the smartwatch as observed on Reddit?

Through the topic analysis on the textual data from Reddit, the authors observed three significant topic threads consisting of capability, battery, and screen and display. Based on the results of the dynamic topic model analysis of the three topic threads, the authors can identify how users perceive their smartwatch from the remediation perspective.

Many users were interested in the functions of smartwatches mainly for healthcare and fitness. However, the smartwatch locations were shown to be different depending on their perceptions on the smartwatch. The authors were able to observe that some users wear the smartwatch not only on the wrist but also on the other parts of body (e.g., ankle). If we look at the two ways that remediation can occur, immediacy and hypermediacy, we can infer that the smartwatch has failed to remediate the smartphone in either way; the user is not immersed in the content that the smartwatch provides because of the unnatural presentation, nor is the smartwatch perceived as having a variety of interaction windows comparable to a smartphone's. The discomfort that the user appears to have can stem from failed remediation; users perceived the smartwatch more as a set of functional sensors rather than a watch or smartphone. From the enactive cognition perspective, this implies that users have to build new cognitive structures because they have to interact with their smartwatch in new ways through its wearable form; something which contributes to the experienced discomfort. In other words, the smartwatch has failed to provide an archetypal way to use the remediated content that it provides, since it has not remediated the contents of the smartphone appropriately. The user perception had to change to use it, and, at the same time, it heavily depends on the distributed cognition that it has with the smartphone; the remediation has failed.

Since the release of the first smartwatches, the battery issue has been pointed out as a critical problem. In this analysis, the authors observed that the battery issue was one of the important topics related to the smartwatch. From the remediation perspective, the battery problem can be considered to be a factor that weakens the immediacy of the smartwatch. As users do not fully utilize several functions of the smartwatch because of the battery limitation, they fail to be immersed in the content which the smartwatch provides. An interesting point that the authors observed in the analysis was that many users regard the battery issue as a trade-off problem. They consider that the battery life depends on the number of functions in the smartwatch, and choosing an appropriate smartwatch therefore depends on personal context and preference. From this observation, the authors can assume that there are two types of smartwatch users: users who pursue high immediacy of the smartwatch, even though it provides a limited set of functions, and users who pursue various functions of the smartwatch although it has low immediacy because of the limited battery life.

The screen and display issue was also shown as an important topic in the analysis. The authors observed that the display and screen issues have decreased over time and that the keyword "display" has steadily been replaced by a manufacturer name, "pebble." Also, the appearances of other keywords in the topic thread, like "price", "new", and "good," have increased over time. Based on these patterns, the authors suppose that the smartwatch market has been segmented and several representative products have replaced some expressions related to display. This phenomenon indicates that users tend to focus on the representativeness, rather than on the detailed properties of the screen or display (Kahneman and Tversky, 1972). From the remediation perspective, it can be observed that a representative name of a product or manufacturer has started to overpower the display specifications of smartwatches.

Through the qualitative review of the posts and contents, the authors also examined that some users hesitate to buy a smartwatch because of expected or experienced problems. One of the problems was the duplicative information in functions; some users failed to find special reasons for using a smartwatch. This also supports the authors' statement that the heavy dependency on the smartphone does not remediate the contents of the smartphone at the same level. A certain amount of functions, provided by the smartwatch, require a connection with a smartphone. The information is mediated by a smartphone, and the smartphone is remediated by the smartwatch. Thus, the information should be remediated by the smartwatch. However, because of the low levels of immediacy (i.e., users are not fully involved in the functions of the smartwatch because of the limitation of battery life) and hypermediacy (i. e., users perceive the smartwatch as a set of sensors rather than a watch) in smartwatch, the information is not appropriately remediated.

RQ2. How can the smartwatch be improved considering the findings from RQ1?

Results show that several smartwatch manufacturers mainly focus on the special functions of the smartwatch. In many advertisements, manufacturers emphasize that their smartwatch can provide a new and original user experience. Several researchers have suggested some unique functions of the smartwatch, such as gesture-based-controls (Wang et al., 2015; Xiao et al., 2014; Xu and Lyons, 2015; Xu et al., 2015), but it is too early to decide if these functions will be successful.

Although a number of smartwatch functions are actually duplicative with those of the smartphone, some unique functions of the smartwatch, such as the heartbeat sensor, have attracted many users. Through the dynamic topic model analysis, the authors have identified that many users were interested in healthcare and fitness functions of smartwatches. It is not clear which came first, but several smartwatch manufacturers actually have emphasized the fitness and healthcare functions of their smartwatch in their advertisements. The results from the healthcare and fitness topic suggest that users employ various wearable styles for their smartwatches. Where several smartwatch manufacturers have mainly emphasized the advanced software values of the smartwatch that are differentiated from the traditional watch, users were not restricted to the hardware form of a normal watch. Rather, users have tried to find their own suitable ways of using the smartwatch.

This may suggest that the future appearance of the smartwatch may change; the authors predict that the current smartwatch will be available in various (wearable) forms. The functional uniqueness of the smartwatch has decreased, considering the functions of other smart products, such as smart glasses, smart bands, smart rings, smart shoes, and even smart underwear. The various trends in wearable devices predict that a greater amount of smart products will become available for users to choose from. It is therefore a question to what extent the smartwatch in its evolution will be fixated on its 'watchness,' that is, its resemblance to an ordinary watch.

Clearly, one of the main challenges in these smart devices is the battery life. It is a big obstacle that prevents users from being immersed in the smart devices. As many manufacturers already recognized, the battery capacity should be improved continuously. However, the authors observed that many users of the smartwatch have regarded it as a trade-off problem; as more functions are provided, more battery capacity is needed. From this observation, the authors can draw two suggestions for smartwatch manufacturers: the manufacturers should keep finding ways to improve the battery capacity as they have done before, but they should also find an optimal position between the number of functions and the battery life. Improving the battery specification requires a lot of time and effort for these companies, and should therefore be limited. However, since users perceive the battery issue as a trade-off problem, the manufacturers can find the optimal point for the trade-off problem. Through survey or interview methods focusing on the users, the manufacturers may find their own solutions to the battery issue.

Several competitors have segmented the smartwatch market. The authors observed several names of smartwatches in the topic threads (2, 3, 7, and 10) of the dynamic topic model analysis. In topic thread 9 (Screen & Display), the authors captured the "display" keyword, which was over time replaced with a name of a smartwatch manufacturer, "pebble". Users have started to mention product names, rather than describing details of smartwatch displays. This phenomenon suggests the importance of brand marketing, which is one of the important factors that make successful businesses representative (Nedungadi and Hutchinson, 1985). In this study, Pebble was shown to be a successful company which has strong representativeness in the smartwatch market; Pebble has emphasized the simplicity of their smartwatch, especially for the display (gray and black) and battery life. Likewise, smartwatch manufacturers can investigate their own ways to emphasize their product identity. A smartwatch which has a clear identity will build a strong representativeness and user base.

9. Conclusion

This study shows that the discomfort that the user appears to have with the smartwatch stems from failed remediation; users perceive the smartwatch more as a set of functional sensors rather than a watch or smartphone. This implies that users must build new cognitive structures to interact with their smartwatch in new ways through its wearable form. In other words, the smartwatch has failed to provide a conventional way to use the remediated content that it provides, since it has not remediated the contents of the smartphone appropriately: the users' perception had to change to use it, and, at the same time, it profoundly depends on the distributed cognition that it has with the smartphone.

Several companies have released many smartwatches with big expectations for sales, but many of them were not as successful as the companies expected. Through the dynamic topic model analysis, this study investigated the users' perception of the smartwatch and suggested future ideas for the smartwatch. The findings of this study can be summarized into three points. First, users tend to perceive the smartwatch not as a kind of watch but a set of functional sensors. Thus, the wearable forms of the smartwatch can be different, depending on the users' styles, and various wearable devices will enable the users to wear the set of sensors to satisfy their needs. Second, users consider the battery life of the smartwatch as being important but also regard it as a trade-off problem. Hence, the manufacturers should keep finding a way to improve the battery capacity, while investigating an optimal point for the trade-off problem. Third, users tend to express the name of a product or company rather than describing details of a smartwatch's specifications. For this reason, manufacturers should build a clear brand identity that enables a strong representation of the smartwatch.

There are some limitations in this study. First, this study collected all posts and comments during one certain period. However, this study did not distinguish questions from opinions/reviews. To resolve this methodological limitation, further studies could consider other approaches. For example, one could try to focus on questions and answers among actual or potential users. Or, one could try to evaluate words relating to smartwatch use. Second, this study only focused on the subreddit "smartwatch," but there could be lots of meaningful texts in other subreddits (e.g., Android, Apple, and some other subreddits for smartwatch companies). Similar to the first limitation, this limitation could be resolved by focusing on meaningful texts in posts and comments. Lastly, the present study focused on the user opinions from Reddit, but various web forums can also be considered. A comparative study with several family products of the smartwatch could therefore provide richer insights for the future of the smartwatch.

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References

Bolter, J.D., Grusin, R., 2000. Remediation: Understanding New Media. MIT Press, Cambridge, MA..

Cao, L., Tang, X., 2014. Topics and trends of the on-line public concerns based on Tianya forum. J. Syst. Sci. Syst. Eng. 23 (2), 212–230.

Cecchinato, M.E., Cox, A.L., & Bird, J., 2015. Smartwatches: the Good, the Bad and the Ugly? In: Paper presented at the Proceedings of the 33rd Annual ACM Conference extended abstracts on human factors in computing systems (pp. 2133–2138). ACM.

Choi, J., Kim, S., 2016. Is the smartwatch an IT product or a fashion product? A study on factors affecting the intention to use smartwatches. Comput. Hum. Behav. 63, 777–786.

Gartner, 2016. Smart machines Gartner IT Glossary.

Gerrish, S., Blei, D.M., 2010. A language-based approach to measuring scholarly impact. In: Paper presented at the Proceedings of the 27th International Conference on Machine Learning Haifa, Israel.

Hutchins, E., 1995. Cognition in the Wild. MIT press.

IDC, 2016. Smartwatch Market Declines 51.6% In The Third Quarter As Platforms And Vendors Realign, Idc Finds [Press release]. Retrieved from https://www.idc.com/getdoc.jsp?containerId=prUS41875116.

Kahneman, D., Tversky, A., 1972. Subjective probability: a judgment of representativeness. Cogn. Psychol. 3 (3), 430–454.

Kim, K.J., Shin, D.H., 2015. An acceptance model for smart watches: Implications for the adoption of future wearable technology. Internet Res. 25 (4), 527–541.

McLuhan, M., 1964. Understanding Media: The Extensions Of Man. McGrew Hill, New York.

Mihalcea, R., Tarau, P., 2004. Textrank: Bringing Order Into Texts. In: Paper presented at the Empirical Methods in Natural Language Processing (EMNLP), Barcelona, Spain.

Nedungadi, P., Hutchinson, J., 1985. The prototypicality of brands: relationships with brand awareness, preference and usage. Adv. Consum. Res. 12, 498–503.

Parra, D., Trattner, C., Gr, C., GtnHurtado, M., Wen, X., Lin, Y.-R., 2016. Twitter in academic events: a study of temporal usage, communication, sentimental and topical patterns in 16 computer science conferences. Comput. Commun. 73, 301–314.

Porter, M.F., 2001. Snowball: A Language For Stemming Algorithms.

Siegal, J., 2013. Smartwatch Sales Set To Explode, Expected To Top 100m Within Four Years [Press release] Retrieved from http://bgr.com/2013/09/27/smartwatch-sales-forecast-2020/.

Varela, F.J., Thompson, E., Rosch, E., 1991. The Embodied Mind: Cognitive Science And Human Experiences. MIT Press, Cambridge, MA.

Wang, H., Lai, T.T.-T., Roy Choudhury, R., 2015. Mole: Motion Leaks Through Smartwatch Sensors. In: Paper presented at the Proceedings of the 21st Annual International Conference on Mobile Computing and Networking, Paris, France.

Wu, L.H., Wu, L.C., Chang, S.C., 2016. Exploring consumerss. Comput. Human Behavior 64, 383–392.

Xiao, R., Laput, G., Harrison, C., 2014. Expanding The Input Expressivity Of Smartwatches With Mechanical Pan, Twist, Tilt And Click. In: Paper presented at the Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Toronto, ON, Canada.

Xu, C., Lyons, K., 2015. Shimmering Smartwatches: Exploring The Smartwatch Design Space. In: Paper presented at the Proceedings of the Ninth International Conference on Tangible, Embedded, and Embodied Interaction, Stanford, California, USA.

Xu, C., Pathak, P. H., Mohapatra, P., 2015. Finger-writing with smartwatch: a case for finger and hand gesture recognition using smartwatch. In: Paper presented at the Proceedings of the 16th International Workshop on Mobile Computing Systems and Applications, Santa Fe, New Mexico, USA.

Zhang, J., Norman, D.A., 1994. Representations in distributed cognitive tasks. Cognitive Sci. 18 (1), 87–122.