Intelligent decision-making of online shopping behavior based on internet of things

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ABSTRACT

The development of big data and Internet of things (IoT) have brought big changes to e-commerce. Different kinds of information sources have improved the consumers' online shopping performance and make it possible to realize the business intelligence. Grip force and eye-tracking sensors are applied to consumers' online reviews search behavior by relating them to the research approaches in IoT. To begin with, public cognition of human contact degrees of recycled water reuses with grip force test was measured. According to the human contact degrees, 9 recycled water reuses presented by the experiment are classified into 4 categories. Based on the conclusion drawn from grip force test, purified recycled water and fresh vegetable irrigated with recycled water are regarded as the drinking for high-level human contact degree and the irrigation of food crops for low-level human contact degree respectively. Several pictures are designed for eye-tracking test by simulating an on-line shopping web page on Taobao (the most popular online shopping platform in China). By comparing the fixation time participants spent on the areas of interest (AOIs), we justify that consumers' online reviews search behavior is substantially affected by human contact degrees of recycled products. It was found that consumers rely on safety perception reviews when buying high contact goods.

1. Introduction

The traditional business model is changed by the expansion of big data and the evolution of Internet of Things (IoT) technologies are changing gradually. E-commerce is the combination of traditional business model and network technology as well as information technology in the information era, so it is facing with both important opportunities and challenges. Internet of Things uses sensor technologies to acquire information, such as the status, location and properties of physical world (Raguseo, 2018; Yang et al., 2018). Increasing number of traditional management model has made breakthrough based on the combination of new technologies such as IoT, big data and cloud storage (Jiang et al., 2018). A sensor can be used to detect physical phenomenons such as humidity, temperature, and even human behaviors. Multiple sensors can be attached to one object or device. For example, speed sensors could be attached to vehicles to detect the speed. It is difficult to obtain such information through traditional sources, but is

capable in the Internet of Things. User behavior and preferences could be known more accurately based on the information, which is of great importance in e-business (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014). Today, new sensor technologies, such as the eye-tracking sensor technology, which was emerged and developed in recent years makes it possible for us to know the behavior characteristics of consumers during the online shopping process better. Further, sensor data could be sent to the cloud, then processed by the big data platform, and ultimately serve for webpage design, e-marketing and also e-advertising (see in Fig. 1).

Therefore, the application of IoT can promote the improvement of consumer performance in electronic market, and it can be used to realize the business intelligence in electronic market (Hashem et al., 2016). The development of IoT technology can not be separated from the progress of wireless sensor networks. Cognitive radio technology (CRT) is used in wireless sensor networks, so the sensor network node can perceive the surrounding spectrum information in real-time, and
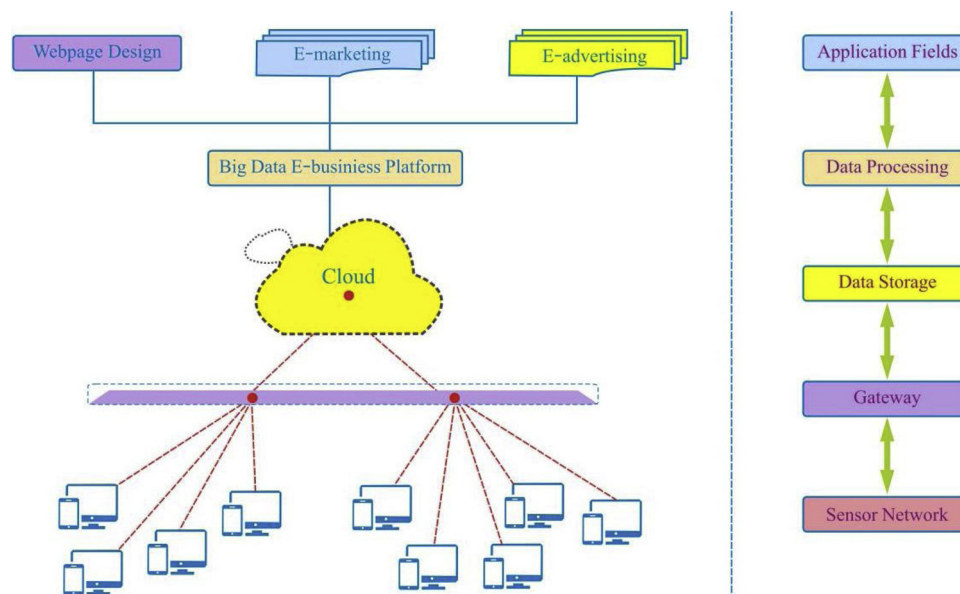
Fig. 1. IoT Framework based on wireless sensor network.

acquire usable spectrum resources, and complete the communication process by selecting the spectrum resources that haven't been used yet (Gholipour, Haghighat, & Meybodi, 2018). Therefore, it can not only be used to relieve the crowdedness of public frequency, but also improve the utilization rate of network in using idle spectrum, and increase the optional working bandwidth of nodes. Nodes can choose idles spectrum for working dynamically, it will reduce the waiting time and conflicts of nodes to get channels. Therefore, it can improve the handling capacity of network and shorten the communication delay of network (Tizvar, Abbaspour, & Dehghani, 2014). With the continuous development of IoT technologies and the emergence of new algorithms and sensors, IoT technologies plays an increasingly important role in our future lives (Qiang & Zhang, 2013; Wei, Yang, Shen, & Zhou, 2012). In this paper, grip force and eye-tracking sensors are used to analyze consumers' online reviews search behavior.

In terms of e-commerce, big data technology has always been used to analyze the consumers' loyalty, purchasing power, and demand degrees. Different pricing strategies will be designed based on the findings of this analysis, so as to realize business intelligence, which is the development tendency in the future. Items produced with recycled water are among the recycled products. Recycled water reuse contributes to eliminating water pollution and improving water supply, which is of great significance to address the problem of worldwide water scarcity. Therefore, it is essential to research how to promote recycled water reuse and guide consumers to buy items produced with recycled water (Fu & Liu, 2017). In the past 100 years, human water demand was 8 times higher more than before (Tie, Wada, & Jcjh, 2017). Human activity has been the dominant factor that affects natural water circulation system. Its implications are so severe that the environmental carrying capacity has been broken, which has triggered irrevocable destruction to the ecosystem. In urban areas where accommodate dense industries and people, the gap of demand and supply for water resources has been acute (Fu, Li, Liu, & Wang, 2018). Therefore, it is of necessity to combat water scarcity in socioeconomic development by replacing freshwater with alternative water sources (Fu, Liu, Wang, & Wang, 2018).

Recycled water reuse in modern society can be traced back to the mid-19th century. However, before 1990, due to the backwardness of sewage treatment technology, the recycled water can only be used for agricultural irrigation in backward areas. However, in the following 10 years, with the rapid development of science and technology, the recycled water with advanced treatment has been directly or indirectly used as drinking water source in some developed countries (Price & Fielding et al., 2012). Nowadays, sewage treatment technology has been developed to produce recycled water that can meet the water quality standard for any needs. However, in reality, the reuse of recycled water is still limited to several uses as it was decades or even 100 years ago without any progress (Zhuo & Huu et al., 2013). The reason why the reuse of recycled water can not be transformed into real productivity despite of the fact that it already broken through the technical difficulties is the resistance of the reuse technology of recycled water. As early as the end of last century, scholars have keenly realized that backwardness of technology is not the biggest obstacle for the publicity of recycled water reuse project, but the public's psychological unacceptability. Since then, many research and engineering examples have repeatedly confirmed that public exclusion of recycled water reuse projects is a key factor affecting its publicity (Dolnicar & Hurlimann et al., 2011).

Pollutants in water can be removed by technological method, but it is difficult to remove the public perception of sewage dirty. The public often reject to use recycled water reuse (Ching, 2015) because of the disgust that recycled water is "Toilet to Tap". This phenomenon was discovered by scholars as early as the 1970s and described as the public's aversion to the impurity of recycled water (Hui & Cain, 2018). In subsequent studies, nausea was shown to have a strong predictive effect on public exclusion for recycled water reuse (Wester et al., 2015). Even if authoritative scientists guarantee the quality of recycled water, but it does not change the public's opinion about recycled water reuse (Fielding, Gardner, Leviston, & Price, 2015). As a result, the reuse of recycled water is more likely to be rejected by the public than other alternative water resources such as rainwater reuse and desalination (Bennett & Mcnair et al., 2016). In recent studies, scholars have defined this phenomenon (once in context always in context) as spiritual contagion (Rozin & Haddad et al., 2015), which means recycled water was sewage water, so it is and will be sewage water all the time. As a result, even though there are no pollutants in the recycled water, the public still can not change their mind about recycled water. Callaghan et al supported this conclusion in a study that they conducted in Australia, it was found that the public tend to associates recycled water with uncleanness and pollution instinctively (Callaghan & Moloney et al., 2012). Some scholars attributed this phenomenon to "the public's pursuit of pure natural products", and found that the public always prefer to get pure natural products, which make it very difficult for them to accept recycled water (Miller, 2006). In Wester's research, we

further found that the potential threat to human health caused by the residues of harmful microorganisms and chemical constituents, and which is a key factor why the public's affection towards recycled water reuse is not positive (Wester et al., 2015).

Despite water treat technologies have been great developed in recent years, a growing number of disease-causing agents have also been discovered, leading to a hanging suspicion among people in terms of the safety of recycled water reuse. When Dolnicar et al. reviewed the documents of recycled water reuse, they found that public acceptance of recycled water reuse has been proved to be associated with the concerns among public on health risk induced by recycled water reuse (Dolnicar & Hurlimann et al., 2011). West et al. further revealed that due to health risk arising from the harmful virus and chemical residuals, people reject recycled water reuse (West, Kenway, & Hassall, 2016). Moreover, lower public acceptance has been found in the recycled water with higher human contact (Wester, Timpano, Çek, & Broad, 2016). Nevertheless, the problem that whether the consumers' health risk perception on various usage of recycled water changes over human contact degrees hangs. For the above issues, this research aims at exploring how human contact degrees of recycled water reuses affect Chinese consumers on-line shopping of products produced by recycled water. This research endeavors to respond to the following questions:

1 How does the degree of human contact change with different recycled water reuse?
2 Does the public cognition on the safety of recycled water products change over the public cognition of human contact degrees of recycled water reuses?
3 How public cognition on human contact degrees of recycled water reuses affect people in terms of prices of the recycled water products?

2. Method

This research refers to the research strategies in IoT field, and use grip force and eye-tracking sensors to detect and capture consumers' online information search behaviors (Cerchecci et al., 2018; Giudice, 2016). To measure human contact degrees of recycled water reuses in a more accurate way, grip force test has been used to ensure consumers' cognition of human contact degrees of recycled water reuses (Thumser, Slifkin, Beckler, & Marasco, 2018). According to the result of grip force test, recycled water reuses are divided into groups, among which two uses that are notably divisive in human contact degrees have been chosen as the research materials for the subsequent eye-tracking experiment. In eye-tracking experiment, the eye-tracking sensor has been used to capture eye movement track of participants when browsing online shopping interface for recycled water products through imitating real online shopping situation. As a result, influences of human contact degrees to different products produced by recycled water has been found.

2.1. Study 1: grip force test

2.1.1. Participants

30 and 57 22-year-old college students in good health condition with normal vision or corrected visual acuity in China, have been chosen to participate in the pre-experiment and formal experiment, respectively (Thumser et al., 2018; Ziauddeen et al., 2012). College students have been chosen because they are believed to be capable cognitively, and familiar with online shopping. Besides, they seem to be more willing to participate in the experiment.

2.1.2. Experiment procedure

Before the experiment commenced officially, 30 college students were invited to the pre-experiment. basic operation of grip force meter are intoruced to participants, and then they are required to grip the grip

force meter with their maximal muscle force every 15 s with orders from instructors. Each participant should grip the grip force meter with their maximal muscle force for 25 times while the instructor recorded the data of grip force meter. Through experimental data and the oral reports of the participants, we found that the participants generally experienced a significant grip slip and felt fatigue after 15 grips. To avoid experimental deviation caused by the decline in grip strength, the total trails number of the official experiment was controlled within 15 times. With the data of pre-experimental grip, it was observed that the first three grip strength data fluctuates greatly, therefore, in the formal experiment, the first three grips are regarded as an experience to help participants using grips and leaving no data logging.

The formal experiment recruited 57 participants from the network, and each one was asked to learn the basics of recycled water and the rules of the device operation, and they are asked to sign informed consent agreement. As the experiment began, participants were requested to face the screen, and to grip the grip force sensor with random force for 3 times according to on-screen prompts to adapt to the grip operation. Then, the participants were asked to press the grip with maximum force according to the on-screen prompts. A total of 3 grips were required, while the instructor was recording the data. After that, pictures of nine kinds of recycled water reused as irrigation of food crops, watering the lawn/garden, drinking, water use for street sprinkler, toilet flushing, water use for parks, car washing, home laundry, and swimming will appear on the screen. During the test, the experiment participants were asked to think about the use of the recycled water that appeared on the screen, and to grip the grip force sensor according to the human contact degrees for this kind of recycled water reuse. The higher the human contact degree for this purpose was, the greater force should be used to hold the grip. On the contrary, the smaller force should be used. Participants were not allowed to view their own test data. Therefore, participants can not know their previous test data accurately before each grip test, and it is difficult to change the experimental results as they wish, so the experimental participants' real perception of human contact degree for different recycled water reuse purposes can be obtained. Therefore, human contact degrees of different kinds of recycled water reuse could be measured according to the measurement reading of the grip force sensor. Layout of the experimental room and field test photo are shown as Fig. 2.
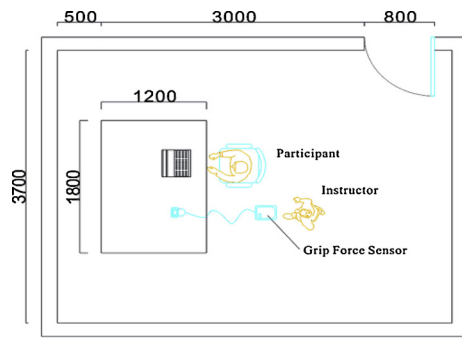
2.2. Study 2: eye-tracking test

2.2.1. Participants

155 healthy college students from Xi'an University of Architecture and Technology and Xi'an University of Science and Technology were recruited to join our eye-tracking experiment. Among them, 14 participants were in the pre-experiment, and 141 participants were in the official experiment. According to the 2016 CNNIC report, people aged 18–25 account for 56% of online consumers in China. They are the main consumers of online consumption. Therefore, the survey results of college students are valid to reveal the behavior and psychological characteristics of the general online consumers (Luan, Yao, Zhao, & Liu, 2016).

2.2.2. Materials

In this experiment, purified recycled water was selected as the item of high degree of contact, and the fresh vegetable that are irrigated with recycled water was selected for the low contact degree. To observe and record the online search behavior of the participants to comments on recycled water products, stimulating pictures for eye movement tests were provided according to the product webpages of Taobao (the most popular online shopping platform in China) (Yu, Li, Chen, Meng, & Tao, 2018). This was to enhance the immersion and experience of the experiment participants who were also ensured sufficient time to view the interface information of each recycled water product in the experiment. The eye tracking sensor used in this study is a non-intrusive, long-

a. Layout of experiment room   b. grip force test

Fig. 2. Layout of experiment room and grip force test photo. a. Layout of experiment room b. grip force test.

distance measurement (PCCR) pupil center cornea reflection technology. Invisible infrared light source is used to illuminate the eyes to produce obvious reflection. Then the image sensor is used to collect the reflection image produced by infrared light source on the cornea and pupil of the user's eyes, and calculate the position of the eyes in space and the direction of the line of sight, so as to realize the tracking of eye movement trajectory. On this basis, the man-machine interaction in the online shopping process is realized. Besides, eye movement trajectories of participants would be traced by the eye tracking sensor during the test.

Considering that the order of the comments may affect the experimental results, this experiment set the comment area into two areas of interest (AOIs) on the left and right sides. In this experiment, the comment area was set as partition display to the left and right area, as the left area the price perception reviews (AOI001), the right area safety perception reviews (AOI002), and comments in the left and right comment areas were about the same length (Liang, 2016). Formation of product presentation and reviews are shown as Fig. 3. Considering that the duration of gaze may also be caused by the difficulty in understanding the pictures, this research screens the comments and selects the textual comments with clear language expression. To ease the influence of the pictures and prices on the attitudes, this experiment selected two different pictures in the same degree of contact, such as Chinese cabbage and lettuce for a low degree of contact. In this research, the gaze duration was used to measure the positive response of the subjects to different types of comments. The fixation duration in different AOIs can explain the cognitive activities and visual attention of the participants.

### 2.2.3. Experimental facilities and experiment procedure

In this research, the test equipment is the iView ETG type eye-tracking sensor produced by SMI company in Germany, including iView PC testing computer, Stimulus PC image display computer and two sets of infrared source and camera installed below. The resolution of the display is 1024 × 768 pixels. Experimental participants were asked to choose to sit in a comfortable position and the seat height is adjustable. The distance between the screen and the experimental participants is about 60 cm. The instructors control the content shows on the Stimulus PC through iView PC testing computer, and the camera installed below the screen of Stimulus PC will capture what the participants found during the test and then lead the data into iVeiw PC testing computer. This testing computer integrates HDFS distributive storage system with high fault-tolerance. Eye tracking sensor can record the eye movement of the subject during the test automatically. The data collection can be completed with iViewX 3.4 software. By collecting high-frequency data that generates every second, it can complete the transformation of information into computer language and then clean the noisy data with built-in operational rule. In the data analysis stage, the researcher uses the BeGaze 3.4 software associated with the eye tracker to analyze and extract the eye movement data. Before starting the experiment, each participant was required to sign an eye movement test informed letter and register personal information. Then it should be learnt that whether the subject is a left eye or a right eye to adjust the eye tracker accordingly, and then perform eyeball calibration on the subject. After the drift correction of the eye tracker, the formal experiment was started. The participants are informed to start a simulated online shopping to browse the shopping interface carefully. After the experiment started, the screen will show "Please browse the next online shopping interface and think about whether you are willing to buy this product", suggesting that the participants experiment is about to begin. Next, a series of online shopping interfaces are presented on the screen, and the participants will be given sufficient browsing time. After each online
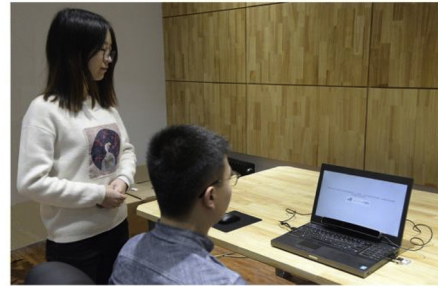

Fig. 3. Product presentation page with 2 AOIs.
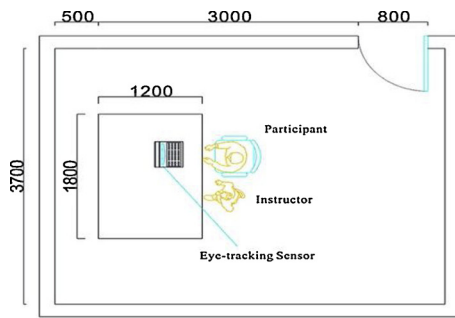
a. Layout of experiment room   b. eye-tracking test

Fig. 4. Layout of experiment room and eye-tracking test photo. a. Layout of experiment room b. eye-tracking test.

shopping interface is presented, the screen will present "Would you like to add this product to your shopping cart." for 5 s to guide the participants to make shopping decisions, making the simulated online shopping closer to the real situation. The eye-tracking sensor will stop recording data when all items have been viewed. Layout of the experimental room and field test photo are shown as Fig. 4.

3. Results and analysis

3.1. Human contact degrees of recycled water reuses

In this research, grip force test has been used to measure the participants' cognition of human contact degrees of different kinds of recycled water reuse. The participants do not know the readings of grip force sensor during the experiment, but only make their decision on how much force given to the gripper based on their own cognition of human contact degrees. This helps the grip force test overcome the problem that the questionnaire data is easily affected by the social context to some extent, which makes the test results closer to the cognition of human contact degrees of recycled water reuses in the subconsciousness of participants. Results of grip force test are shown as Fig. 5.

By analyzing the paired-samples *t*-test results of participants' cognition of human contact degrees of different kinds of recycled water reuse, the 9 recycled water reuse in the experiment can be divided into four categories according to the difference of human contact degrees. In the highest category, including only drinking (DRI), human contact degree of DRI is significantly higher than other kinds of recycled water reuse; in the second category, only including swimming (SWI), human contact degree of SWI is significantly higher than all other uses besides

Fig. 5. Participants' cognition of human contact degrees.

DRI; in the third category, including home laundry (HOM) and irrigation of food crops (IRR), they do not have significant difference between each other in human contact degrees. However, the human contact degrees for both recycled water reuse applications are significantly higher than 5 uses as car washing (CAR), toilet flushing (TOI), water use for street sprinkler (WUS), watering the lawn/garden (WAT) and water use for Parks (WUP). The fourth category includes five recycled water reuse applications: CAR, TOI, WUS, WAT and WUP. The difference in human contact degrees for these five recycled water reuse uses is not significant at $p < 0.001$ Table 1.

3.2. Consumers' online information search behavior

According to the conclusion of grip force test, we selected drinking water and irrigation water of food crops with significant differences in the participants' cognition of human contact degrees. The two products of purified recycled water and fresh vegetables that are irrigated with recycled water were respectively used as representatives of drinking water and irrigation water of food crops with recycled water reuse application, and the stimulating pictures of the eye-tracking test are designed in imitation of the Taobao product interface.

3.2.1. Heat map analysis

Over 80% of information that man acquire from the outside world are obtained from visual system. When the big data can be presented in front of researchers with visual images, researchers can find the information behind the data easily and draw more interesting conclusions from those information. The data visualization in this research uses a theory and technology like computer graphics and image processing technology, and then transform the data into heat maps on the screen for interactive processing. Heat maps refer to the degree of individuals' concerns in one field that they are interested in, it can provide a more intuitional results, so as to find out the concern differences of the subjects regarding to different comment forms. Fig. 6 shows a heat map comparison analysis of the regions of interest of different products produced by recycled water. In Fig. 6(a), purified recycled water is showed. In Fig. 6(b), fresh vegetables are irrigated with recycled water is presented. AOI001 is the price perception reviews area, and AOI002 is the safety perception reviews area. Different color depths describe the degree of attention of the subject. The red-colored areas represent the hottest ones with longest gaze, followed by yellow, green, and blue, and the uncolored areas receive to gaze. Comparing Fig. 6(a) and (b), it can be found that there is a significant difference in the degree of gaze of subject between the purchase of purified recycled water and the purchase of fresh vegetable irrigated with recycled water. For purified recycled water, participants' attention time on safety information comments is significantly longer than the price/performance comments, indicating that the participants are more concerned with safety information. For fresh vegetables that are irrigated with recycled water,
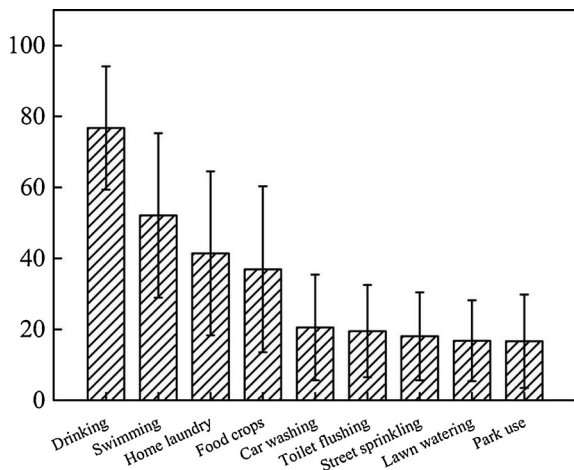
Table 1
Paired-samples *t*-test of human contact degrees.

Name	DRI	SMI	HOM	IRR	CAR	TOI	WUS	WAT	WUP
DRI									
SMI	t = 7.647***								
HOM	t = 10.283***	t = 4.139***							
IRR	t = 11.507***	t = 4.503***	t = 1.171						
CAR	t = 20.472***	t = 10.655***	t = 7.702***	t = 5.139***					
TOI	t = 21.337***	t = 10.458***	t = 7.740***	t = 5.517***	t = 0.688				
WUS	t = 23.096***	t = 12.395***	t = 8.845***	t = 6.349***	t = 1.789	t = 1.115			
WAT	t = 22.869***	t = 11.314***	t = 8.723***	t = 6.553***	t = 2.527	t = 2.021	t = 0.940		
WUP	t = 21.515***	t = 11.424***	t = 8.767***	t = 6.765***	t = 2.609	t = 1.917	t = 1.142	t = 0.097	

Notes: *** significant at p < 0.001.

no significant difference on participants' attention time is found between the price perception reviews, and safety perception reviews. By comparison, the duration of attention to the safety perception reviews was slightly longer than it to price perception reviews.

By analyzing the Heat map, it is concluded that when we are considering whether to add high-touch products such as purified recycled water into the shopping cart, the participants need to spend more time on the safety and quality information of the products, that is, whether the water quality in the comments is clear, whether the manufacturer is formal, whether there are water quality monitoring results of authoritative organizations, etc.; when we are considering whether to add low contact products such as fresh vegetables that are irrigated with recycled water into the shopping cart, the participants pay attention to the price/performance and safety information of the products, that is, whether the goods are safe or not in the safety test and whether the price in the comments is cheap.

3.2.2. Fixation time comparison

The gaze time histogram specifically depicts the relative gaze time of the participants in different areas during the entire browsing process. Fig. 7 shows the gaze time comparison results for different reviews of different contact levels. In Fig. 7(a), the fixation time diagram of the product with high contact degree is shown, and in Fig. 7(b), the gaze time chart of the product with low contact degree is shown. The horizontal axis represents Time, and the vertical axis represents the time that the gaze stays in the area of interest. Different colors in the figure indicate different regions of interest. In Fig. 7(a), yellow indicates the price perception reviews region (AOI001), and purple indicates the safety perception reviews region (AOI002). In Fig. 7(b), dark blue indicates the price/performance comment region (AOI001).), and light blue indicates the security information comment area (AOI002). In Fig. 7(a), the purple area (AOI002) in the figure is significantly larger than the yellow area (AOI001), indicating that the subject's relative gaze stay time for safety information comments is longer. In Fig. 7(b), area of the dark blue area (AOI001) and the light blue area (AOI002) also show that the participants are concerned about both safety information reviews and price-performance comments on products with low contact degree.

3.2.3. Interactive effect analysis

Accurate eye movement data of 141 people has been obtained in the eye movement experiment. To compare the differences of information search behaviors of the participants in the same group, the paired *t*-tests were performed on the gaze duration of different AOIs between the two products in each group. Taking the highly human contact product purified recycled water as an example, the paired *t*-test of the two reviews of purified recycled water 1 and purified recycled water 2 was performed, and the difference between the two sets of data was found to be not significant at p < 0.05 (t = 1.274, p = 0.204). Therefore, it can be verified that there is no significant difference in the gaze time of different AOIs between the two groups of participants in the high

human contact group. Similarly, the gaze time of different AOI in the low human contact group was also confirmed to be no significant difference (t = 0.559, p = 0.577). Thus in the next interaction effect test, the high human contact group and the low human contact group could be selected respectively.

A two-factor analysis of variance was used to test whether there were significant differences in the gaze duration of different AOI between two shopping websites as the purified recycled water and fresh vegetables that are irrigated with recycled water (as shown in Table 2). The main effect is p = 0.000 and the interaction effect p = 0.023, which are less than 0.05, indicating significant difference existing in the gaze duration of the participants for purified recycled water and fresh vegetable irrigated with recycled water. There is also an interaction between the content of the review and the degree of contact. Gu verified that participants had significant differences in their attention paid to the price perception reviews and safety perception reviews, when they purchased online products of recycled products with different contact degree.

To learn the difference in the duration of comments between the two different human contact products of the purified recycled water and the fresh vegetables that are irrigated with recycled water, we examined the interactive effects of the product types and review types (see in Fig. 8). For purified recycled water of high contact degree, participants were more concerned with safety information, so that the gaze duration of AOI002 was significantly longer than AOI001. For the fresh vegetables that are irrigated with recycled water of low contact degree, the gaze duration of AOI001 and AOI002 was not significantly different, and the gaze duration of AOI002 was slightly longer than AOI001. It can be seen that as the human contact of recycled products increases, the gaze time of comments on the safety information is increased.

4. Discussion

4.1. Discussion of the findings

With the popularization of e-commerce, the influence of consumer's online reviews on consumer behavior decision-making has drew more and more attention from the public (Neirotti, Raguseo, & Paolucci, 2016). Products produced with recycled water has been choosen in this paper, and it is a distinctive product. By using grip force and eye tracking sensors, this paper studies the differences of consumers' attention to online reviews of different human contact degrees products, so as to find out the causes of public exclusion for recycled water reuse.

Human contact degrees are considered as potential factors affecting public attitudes and willingness to pay for recycled water reuse based on the findings of many researches. However, conclusions about the existence of human contact degrees are often made based on experience, no sufficient and reliable research conclusions can be used to confirm the existence of human contact degrees (Garner, Zhu, Strom, Edwards, & Pruden, 2016). In this study, by introducing grip force test,
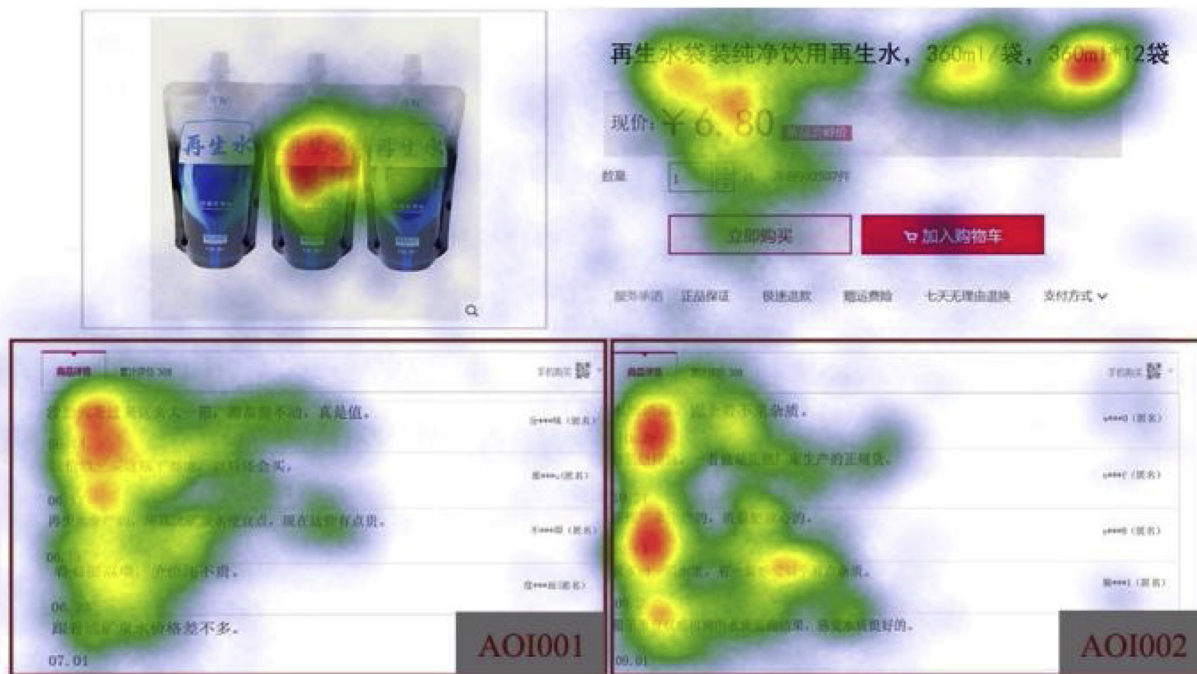
(a) product of high contact degree (purified recycled water)

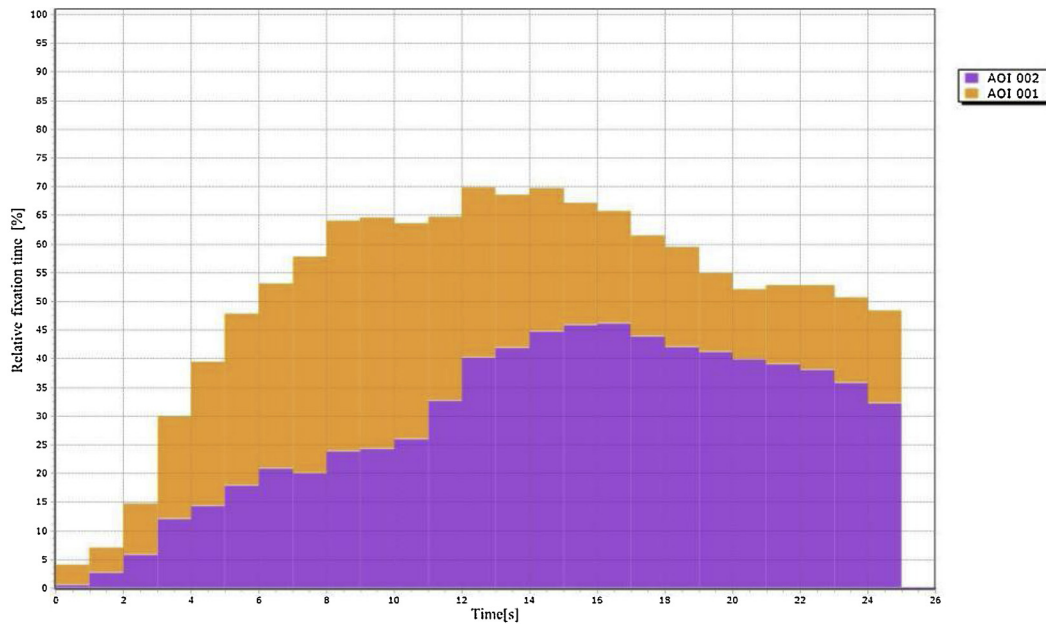(b) product of low contact degree (fresh vegetable irrigated with recycled water)

Fig. 6. Heat map. (a) product of high contact degree (purified recycled water). (b) product of low contact degree (fresh vegetable irrigated with recycled water). (For interpretation of the references to colour in this figure text, the reader is referred to the web version of this article.).

the influence of social context on experimental results is reduced effectively, and more accurate experimental results are obtained afterwards. Accurate measurement of human contact degrees for different reuse of recycled water is a useful supplement to previous studies, and it can be used to provide a reference for the classification of experimental materials of eye tracking test.

The factors why recycled water is refused by many people are very complicated. Although many researchers have made fruitful explorations on this issue, there is no clear knowledge about the mechanism of various factors for public exclusion of recycled water reuse (Fielding, Dolnicar, & Schultz, 2018). In this study, eye tracking sensor was used to track the search behaviors of two different types of consumers' online reviews (price perception and safety perception reviews) regarding to participants with different human contact degree of recycled water

(a) product of high contact degree（purified recycled water）
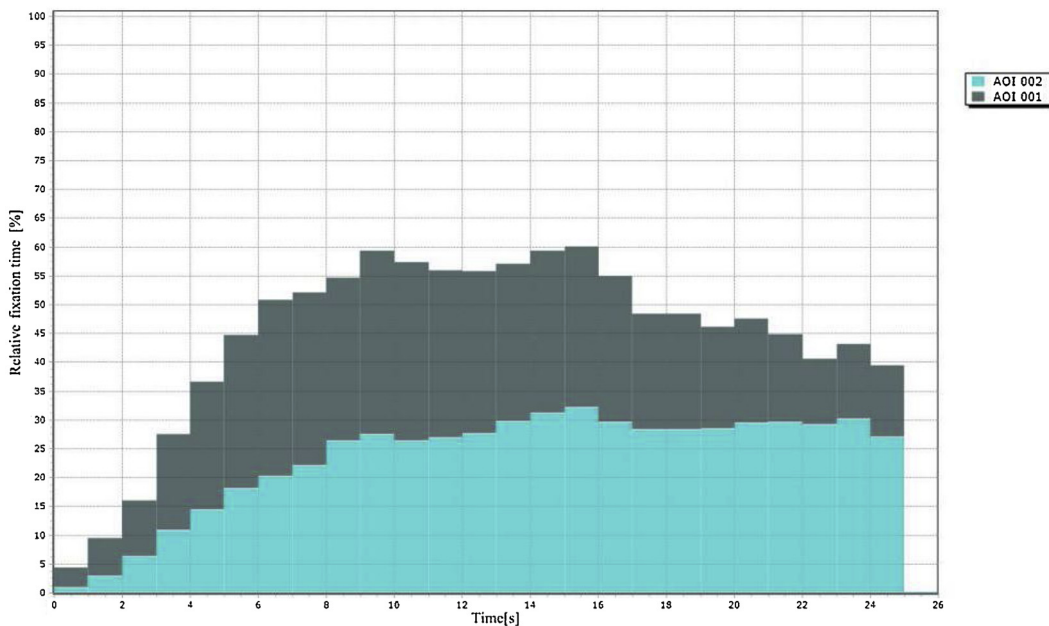
(b) product of low contact degree（fresh vegetable irrigated with recycled water）

Fig. 7. Fixation time comparison results. (a) product of high contact degree(purified recycled water). (b) product of low contact degree(fresh vegetable irrigated with recycled water). (For interpretation of the references to colour in this figure text, the reader is referred to the web version of this article.).

products. The participants have higher concern on safety perception reviews for recycled water products with high human contact degree. This paper supplements the research on influencing factors of public acceptance of recycled water reuse from the perspective of usage of recycled water reuse with different human contact degree based on public preference information.

4.2. Theoretical implications

In order to explore how human contact degrees of recycled products

influences consumers' online reviews search behavior, products produced by recycled water were selected as the specific research object. The eye-tracking sensor is used to simulate the man-machine interaction in the online shopping process, and the interaction between human contact degrees and review types is found, which provides a theoretical basis for exploring characteristics of consumers' online information search behaviors. In this research, human contact degrees were selected as the scales for different types of recycled water reuse, and the research ideas in the field of ergonomics were used. The grip force test effectively overcomes the shortcomings of the traditional questionnaire

Table 2
Two-factor analysis of variance result on gaze duration of products of different contact degree.

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	333.539	3	111.180	9.491	0.000
Intercept	20,109.039	1	20,109.039	1716.718	0.000
Review type	185.120	1	185.120	15.804	0.000
Human contact degrees	87.205	1	87.205	7.445	0.007
Review type* Human contact degrees	61.215	1	61.215	5.226	0.023
Error	6559.645	560	11.714		
Total	27002.224	564			
Corrected Total	6893.185	563			

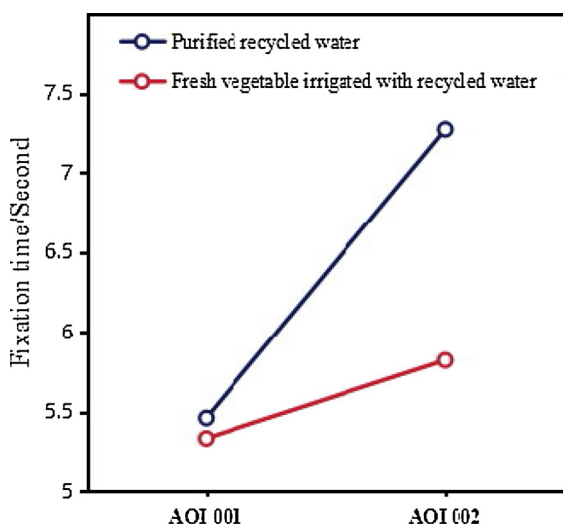*Notes*: calibration model R^2 = 0 0.048, adjusted R^2 = 0.043.

Fig. 8. Interactive effects of product types and review types.

measurement method, which is affected by the social context. The measured data of human contact degrees is therefore much closer to the data of true feelings. Grip force and eye-tracking sensors are used in the research of consumer online shopping behavior, which realizes the combination of IoT technology and electronic market research, and provides new ideas for consumer online shopping behavior research.

The use of eye-tracking sensor in capture the eye movement of consumers in online shopping can help us to know the characteristics and rules of consumers' online reviews search behavior, and make the realization of business intelligence easier. Besides, the research results in this paper can be used to guide the design of online shopping website, so the production introduction can be displayed on the website properly to avoid the distraction of useless information. Then, the consumers shopping performance can be improved as well.

4.3. Practical implications

According to the research results of this paper, when the government formulates water quality standards for different recycled water reuse purposes, except for technical considerations, people should also consider the differences in subjective perception levels of different recycled water reuse applications. For applications such as the use of recycled water for high contact degree as direct human consumption, technical standards should be used to set the highest possible water quality standards to dispel potential consumers' concerns about recycled water; and for recycled water use of low contact degree such as car washes, people are more concerned about the economics of using recycled water. Therefore, for this type of use, the water quality

standards may not be excessively required under the premise of ensuring user safety. It would be more proper to make more profit margins for companies that use recycled water by using the invisible hand of the market to the promotion of recycled water reuse of low human contact degree.

In this paper, eye-tracking sensor has been used to acquire the online shopping behavior data of consumers successfully, and those data are difficult to obtain through traditional sources. Then, those data are used to analyze the characteristics of consumers' online reviews search behavior. The knowledge of consumers' online shopping behaviors could have great importance for webpage design, e-marketing and e-advertising. Although the technology is very limited, some similar human behavior sensors like eye-tracking sensors use to realize human behavior recognition are usually expensive and complicated in operation. At present, human behavior sensors are used in research field, and it is difficult to be applied in commercial area widely. However, with the development of future technology, human behavior sensor would become widely used in real life just as other wireless sensors, such as vehicle speed sensor and position sensor. At that time, wireless human behavior sensor network would be used to acquire data of online consumers' shopping behaviors and use cloud storage technology and big data processing technology for data mining. This will enrich our understanding of consumers' online shopping behaviors, so we can improve consumers online shopping performance and realize e-business intelligence.

5. Conclusions

In order to find out the different types of information that consumers have for different human contact products produced by recycled water, firstly, different kinds of recycled water are classified according to the degree of human contact. The two groups with significant difference in human contact degrees were selected as experimental materials for simulating online shopping experiments. The eye-tracking sensor was used to record the reviews search behavior of the participants when browsing the online shopping interface, and by comparing the fixation time of AOIs represented by different types of reviews for consumers, this paper verified the impact of human contact degrees of recycled products on consumers' online reviews search behavior. Conclusions are as follows:

First, the public cognition of human contact degrees of different kinds of recycled water reuse is accurately measured. Based on the results of grip force test, the contact degree of the 9 recycled water reused in the experiment with the human contact degree was accurately measured. The 9 recycled water reused were ordered according to human contact degrees by comparing the normalized grip force test data. Through the paired *t*-test, the nine types of recycled water reused were divided into four groups with significant difference in human contact degrees.

Second, verifying that the degree of contact has a significant impact on the level of consumer attention to online content. Eye movement experiments can be used to confirm a significant interaction between the degree of contact and the content of the review, meaning that the degree of contact can influence consumers' attention to online reviews of recycled water products. As the degree of contact increases, consumers begin to become more concerned about the safety perception reviews.

Third, consumers rely more on safety perception reviews to make purchasing decisions when purchasing high contact degree items. Eye movement experiments have confirmed that consumers are more concerned about the safety perception reviews on web pages when purchasing high contact degree products. For low contact degree products, consumers have no significant difference in gaze duration for safe perception reviews and price perception reviews on web pages, and attention to safety perception reviews was only slightly higher than the price/performance reviews.

5.1. Limitations and future research directions

Due to the limitations of the researcher's ability and the fact that the participants in this test are all college students, there may be some limitations in the representativeness of the sample. In future researches, we will try to use wireless network to link sensors, so that experiments can be carried out in different places at the same time, and the number of experimental samples can be expanded, which can also avoid the impact of laboratory environment on the experimental results effectively.

At the same time, this experiment puts different types of reviews on the left and right sides of the screen, but issue of the influence of the left and right position on consumer attention haven't been considered. The experimental design should be improved in future researches while the impact of review positions has been taken into consideration.

In addition, a considerable number of experimental participants said after participating in the experiment they are often attracted to the negative comments in the comments when they are watching the shopping page, which also gives us considerable inspiration, therefore we will continue to design research on the effect of positive and negative emotions on the promotion of recycled water reuse; the "yuck" reported by some participants in the use of high-level recycled water reuse (such as the use of recycled water for drinking) also brought us some new research ideas. In the follow-up researches, we would continue to try to introduce sensors such as event-related potential that can sensitively detect human mood fluctuations to promote the "yuck factor" that limits the reuse of recycled water.

In this research, grip force and eye tracking sensors are used to study consumer's online reviews search behavior in the laboratory. It is just a superficial attempt to combine IoT with consumer behavior research. In future research, more efforts are needed to explore how to use wireless network sensors to detect consumer behavior, so the market managers can understand the internal mechanisms behind every consumer decision better.

Conflicts of interest

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ijinfomgt.2019.03.010.

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