

Ceiling Fans: An analysis of pull-chain controls

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Introduction:

Ceiling fans are very commonplace yet efficient products used in most residential as well as commercial settings around the world to provide thermal comfort in closed or open areas by inducing air movement via the rotation of blades. Researchers have confirmed that elevated air movement has the potential to increase perceived thermal comfort in warmer temperatures by increasing the rate of perspirative evaporation (Present et al., 2019). Ceiling fans have been extensively studied for their energy efficiency and ability to provide comfort to the occupants but they still need some exploration in the usability and user experience domain. According to a survey conducted in the year 2013, an average household in the USA owns a mean of 3 light-kit-enabled ceiling fans with over 57% being operated by a combination of wall switches for power control and pull chains for light and speed control (Kantner et al., 2013). Although with advancing technological innovations we notice an emergence of sophisticated remote-operated smart fans, the study points out that almost half of the population is using fans with a reminiscent technology from the previous era. i.e. pull-chains. With this research paper, we will analyze the pull-chain controlled light-kit-enabled ceiling fan from a usability point of view. Further, we attempt to delve into the underlying psychological foundational principles that govern the user experience, and finally, we will propose a solution that builds onto these principles and enhances the associated experience of the fan.

The current investigation is conducted in a closed room with ambient room temperature and uses the Hampton Bay 52-inch Rothley II ceiling fan (figure 1) as the primary testing prop. The fan is a standard-size ceiling fan with 5 blades, a center-mounted light kit, and two metal-ball chains hanging from the center light panel to control the lights and speed. The chains are identical in

every aspect except for the lengths to discriminate between light control and speed control. With no other distinguishing factor, the shorter chain controls the speed of rotation, starting from turning the fan on at low speed with the first pull, medium speed with the second, and high speed with the third pull. And the longer chain controls the state of light with alternate pulls to switch the light on and off.



Figure 1. Hampton Bay 52-inch Rothley II ceiling fan.
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Five university students (four male, and one female) with varying levels of experience participated in the study to try and operate the fan. Each trial was conducted individually for

each participant and was preceded by a pre-test interview and succeeded by a post-test interview.

A detailed description of pre-test questions, tasks, and post-test questions is as follows:

Pre-test questionnaire:

1. What different kinds of ceiling fan operating/controlling methods are you familiar with?
2. How long have you been using or have used these fan controls?

Task Description:

Initial Condition:

Participants were informed that the wall-mounted power switch connected to the fan's power supply was left on. Using the pull chains, the light kit and fan motor were set in the off-state.

And also that the fan may have 3 or 5 speed-states to choose from.

Task:

By selecting the correct chain try to find out the available rotational speed states of the fan using that pull chain and then set the speed to the medium state available.

Post-test questionnaire:

1. Why did you pull this chain first?
2. How was your experience using this fan?

Observations:

On average, each participant took about 8 minutes to complete the pre and post-test interviews, briefing about the initial conditions and the actual task. The pre-test interview revealed that all of the participants have used wall-mounted regulator knobs to adjust the fan speeds for more than 15 years. 3 out of 5 participants have occasionally used fans with remote control to switch on or off the fan or to adjust the rotation speed. Astonishingly, it was also revealed that all 5 participants have been exposed to the pull chain-operated ceiling fans for at least 4 months at the time of the test, but only 2 of them claimed to be familiar with using these fans. When probed about the reason, later in the post-test interview, 3 of 5 participants stated that they were not comfortable with using the pull chain controls. During the task, only one of five participants was unable to successfully complete the task of identifying the correct number of speed variations and setting the speed to the medium state available. Further, 2 participants initially pulled the wrong chain, which toggled the light kit in on-state, which they corrected after a subsequent pull of the same chain. 4 out of 5 participants expressed discomfort verbally when they were judging the speeds of the fan in the different speed states and then comparing the current state with the previous state. We also recorded the total time taken by the participants to select the chain, identify the available states of speed, and set the fan to medium speed. The time data (figure 2) thus recorded matched the extent to which the users expressed their discomfort with the user experience in the post-test interview. When answering about the experience of completing the task the user generally expressed a negative sentiment towards the pull-chain controls, while stating that it was difficult for them to perceive the difference between the speed states of the fan along with remembering what the previous state was.

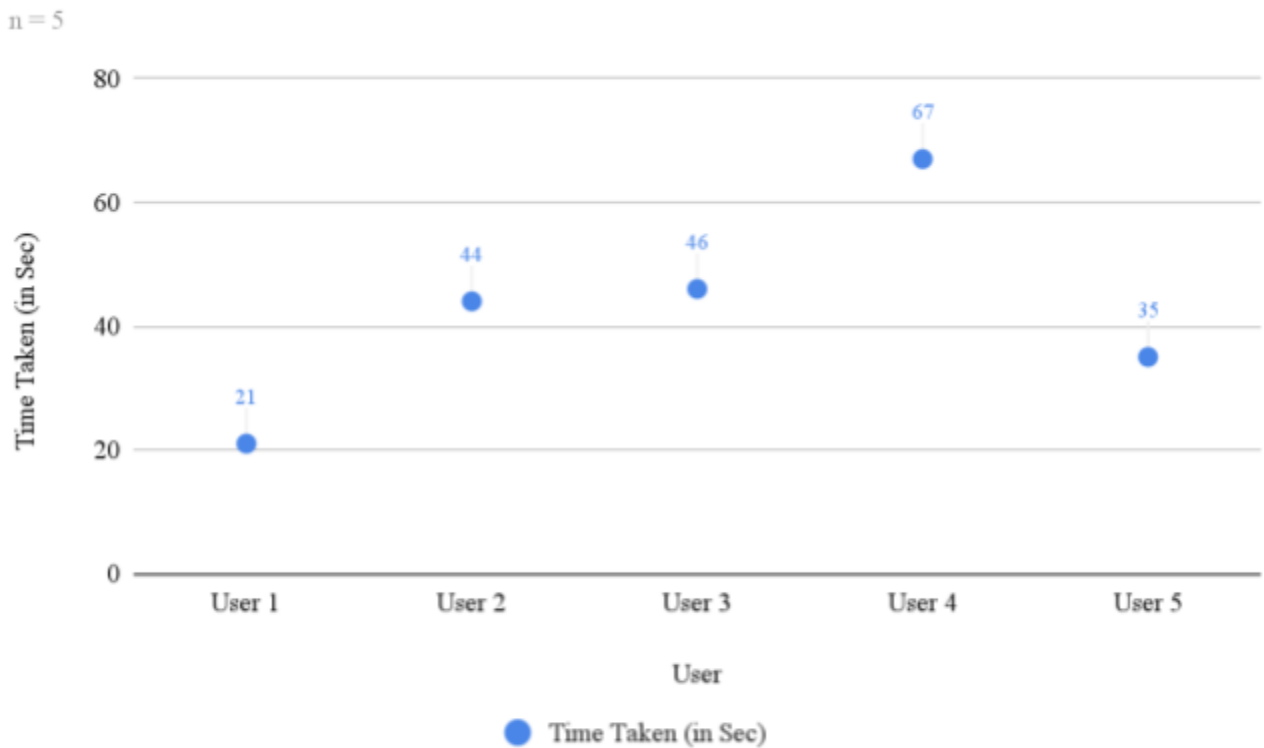


Figure 2. The time taken by participants to perform the given task.

Psychology Foundational Principles:

Control Discrimination: From complex systems like airplanes to simple systems like pull chains of ceiling fans, the usability of any system is highly influenced by how the user interacts with the system. The primary source of the user input to any system is the controls that are made available to the user, hence it is of prime importance that the said controls are easily identifiable, accessible, and discriminable at any given time to ensure a positive interaction and to avoid any unnecessary control activations (Lee et al., 2017).

In the context of this study, we observed participants dealing with the issue of accidental control activation when they try to guess which chain should be used to control the motor of the fan, in

order to get the fan started. As stated earlier, the two critical controls present in the fans are just the two metal-ball chains with identical structure and color and with no labeling to aid the user, they are forced to rely on their memory to recall what length of chain is associated with what action. One of the arguable points with distinguishing fan controls is that along with the difference in the length, the spatial location of chains may also help in discriminating between the controls. However, research findings indicate that one dimension can become more perpetually salient than others dimensions, thus reducing any intended redundancy gained by the spatial difference (Thompson & Markson, 1998). Therefore it is imperative to good design that controls are made discriminable with more than one salient factor, which can be easily achieved using various methods like color coding, or the use of icons or labels near chains to ensure ample redundancy gain. But for proper visual identification and coding, care should be taken to maintain the constancies of shape, color, lightness, and location across different viewing angles (Goodale & Milner, 1992).

Visual Perception: Once the user has identified the correct chain to pull and the fan is set into motion, the next enormous task that the user faces is to look at the fan blades and guess the speed with which they are rotating, and then compare it to the resulting speed when the chain is pulled again. The task inherently invokes the use of memory to compare the speeds, which will be discussed later in the paper. But preceding memory is the ability of the user to perceive the rotational velocity (speed states) of the blades of the fan at different states when the switch is pulled.

A bi-experiment study by Pani et al. (1995) suggests that strong constraints (like the fixed position of the fan and the limitations of human physiology to look exactly parallel to the plane rotation) on the human ability to imagine rotations extend to the human perception of rotation.

This position is again bolstered by the findings by Massironi & Luccio (1989) which state that the axis and planes of rotational motion must be aligned with a salient spatial reference system, typically the main directions of the environment or the intrinsic reference system of the object, for people to predict and successfully perceive the outcome of a rotation. But, while operating the fan's pull chains and tilting the head to look up the blades, the reference plane of the observer (user) gets aligned in an oblique way to the plane of rotation, thus making it difficult to perceive and encode the current speed of rotation into the memory for later comparison. As it remains, providing a feasible solution to improve human perception is not possible as of now. Hence, the next best solution is to at least provide users with some metaphoric way with which they can associate the speed of rotation and possibly get immediate feedback if they try and change the speed state.

Memory: In the task described earlier in the paper, the implicit or explicit use of memory is evident at multiple points. It starts with recalling the association between a variation of a dimension (length of chain) and its represented function (controlling the light or the motor). Once the fan is in motion, the focus of memory then proceeds to encode the rotational speed data from visual perception to sensory memory and short-term memory. The users might need to recall if they wish to learn the number of variations available or to compare the previous variation with the current one. Also, if the users' attention is diverted for a significant amount of time, then they have to rely again on memory to recollect the placement of current speed variation in the pre-established order of states. In other words, if the user currently sets the speed of the fan to a medium setting and gets disturbed by some event elsewhere, as there is no indicator on the fan, the user has to solely rely on their perception to judge the current speed and

then try to recall from memory if this speed matches with the low-speed setting, medium speed setting or the high-speed setting.

The center of the fan is a light kit and motor which are following a rotation motion, whereas the blades are following a revolutionary movement with the light kit as their central axis. The information a user perceives from observing this motion is first stored in sensory memory and then pushed to short term memory. Sensory memory is described as the capability of holding sensory information obtained from stimuli received from the senses, has a very short retention time, and acts as a buffer for information transferred to short term memory via selective attention (Amin & Malik, 2013). This mechanism of perception and memory works fine with translating or looming motion, but when it comes to rotational or revolutionary motion human memory fails to create any reliable memory traces (Price & Gilden, 2000). In a series of 6 experiments studying the representation of motion and direction, researchers Price & Gilden (2000) attribute this weakness of memory to the constant change of orientation that the object undergoes during rotational motion. The ceiling fan under consideration relies heavily on human memory, which is not optimally dependable when it comes to rotational motion, and this failure in the design is reflected in the strong user dissatisfaction recorded in this study.

Bottom-up processing: Additional to the visual perception of moving fan blades, the sensitivity towards surrounding air velocity and the induced thermal variation influences the user's ability to perceive different speed states available in the ceiling fan. Thermal variation is a byproduct of air movement in the user's vicinity, but its perceived comfort is largely dependent on the surrounding temperature. According to Toftum (2004), the way that a person perceives air movement depends on a variety of environmental factors, including air temperature, air temperature fluctuations, and air velocity, as well as individual factors like activity level and

general thermal perception. In the same paper, Toftum (2004) mentions that in warmer climates high air velocity is preferred whereas in colder climates air movement poses the threat to induce draught (current of air in confined closed spaces). And, localized air movement could potentially increase the sensation of discomfort due to the combined effects of air velocity properties with air temperature and the thermal condition of participants (Todde, 2000).

As these factors are functions of individual sensitivities, environmental conditions, location of the user with respect, and even gender (Todde, 2000 & Present et al., 2019) and can interfere with the user's perception and memory, they can not be relied upon to aid the user in differentiating various states available and have potential to negatively bias the user towards using a ceiling fan in general.

Decision: The combination of control discrimination, visual perception, memory, and various bottom-up sensory inputs have a profound influence on the decision-making capabilities of the participants. During the completion of the aforementioned task, it was clearly evident that although most users were able to complete the assignment successfully, they faced difficulty in making decisions when it came to pulling the correct chain and setting up the fan in a medium-speed state. There was uncertainty with the available choices of pull chains and available choices of speed states. There were design flaws that forced the user to put a strain on their memory in the areas where humans have inherently weak perceptive encoding. Hence, there was an increase in the number of choices and stimuli, which resulted in increased reaction time or in this case, the decision time. This increase in decision time with an increase in available information aligns with the findings of Hicks-Hyman Law (Hyman, 1953).

According to Memelink & Hommel (2012), the automatic priming of task-relevant feature dimensions occurs before the perception and production of an event, which increases the

influence of encoded memory reflected in this dimension on information processing. Thus, task-relevant elements are given more weight than irrelevant ones, increasing the likelihood that they will predominate in the cognitive representation of the entire event (Memelink & Hommel, 2012). Following this line of thought, in the ceiling fan, the dominant task-related feature length of the chain, but due to the absence of any dependable encoded memory associated with this dimension, the shorter chain, the process of information processing, and hence the final decision is botched.

Design Improvements:

Studying the fundamental psychological principles central to operating the pull-chain-based ceiling fans reveals the human memory and the ability to discriminate between the controls as the two most crucial design considerations. A design improvement considering these factors will not only mitigate the risk of accidental control activation but will also decrease the dependence on memory by promoting recognition rather than recall. We propose a design solution that eliminates the need for participants to rely upon visual perception to judge the speed of fan blades and the possible interference due to positive or negative biases due to air movements, thus aiding the decision process. The proposed design solution (figure 3) is based on the use of three icons (with accompanying numeric information representing the speed states. One being low, two medium, three high, and zero off.) to represent the available speed states and an indicator of the current speed state of the ceiling fan. This indicator and icons should be placed in close proximity to the chain responsible for operating the fan motor (the shorter chain) and the indicator must change its indication as soon as the user pulls the chain. To remove any

dependencies on external power sources and to leverage the existing mechanical design of pull chain systems, we propose a physical indicator system as opposed to LEDs with a power delimiter. Additionally, the icon for off-state is intentionally kept separate from the speed-states to produce visual discrimination if viewed from distance.

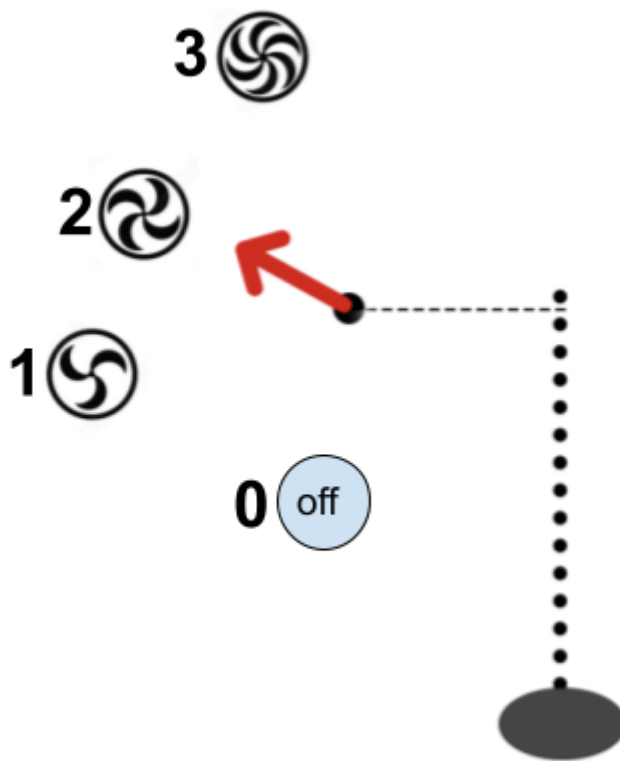


Figure 3. Proposed conceptual design solution.

Roediger (1990) in his research paper titled “Implicit memory: Retention without remembering” posits that the explicit measure of human memory functions on recall or recognition is the conscious recollection of the past. And with enough frequency of use, this explicit measure is transferred into an implicit measure, thus reducing the need for conscious recollection and a strong feature encoding into the memory. By having icons (with an associated number) to

indicate the current speed, the user could instantly acquire the knowledge of all available speed states along with the current speed which is indicated by the indicator. The icons and numbers will assist in the explicit recognition of the available states, and with prolonged use has the potential to be transferred to implicit memory where users will be able to recollect the available states without the need to recall consciously.

Additionally, research by Thompson & Markson (1998) points out the importance of salience hierarchy. The salience hierarchy represents the individual's perceptual sensitivity to the perceived dimensional interactions. More sensitive relationships are located near the top of the hierarchy, while less important relationships are located near the bottom. Thus, the proposed design solution focuses to increase the salience of the shorter chain (speed states/motor control) by placing the indicator-icon system in close proximity to it. This will increase the salience of the length dimension and provide a discriminating factor between the two pull chains.

Conclusion:

The ceiling fan although a simple device, if not designed with sufficient attention to underlying operational psychological principles can cause tremendous frustration to users to the extent of abandonment of the product. In the experimental trial with 5 participants, we found that despite over three months of exposure, they were not comfortable with using the device. The major identifiable reasons behind this discomfort are accidental control activation and confoundment with speed states. Due to the poor discriminability of the pull chains, the users found it difficult to associate any salience to any particular dimension, and they inevitably had to rely on either guesswork or memory to identify the correct control. Further, when the fan was set into motion, the users had to rely on a faulty perception of rotating blades and weak memory associated with rotational motion to determine the available speed states in the ceiling fan, with bottom-up sensory stimuli affecting their perception. And because of this combination of all the said factors, it became difficult for the user to decide on what the medium speed state is, causing further frustration and incentive to abandon the product.

After a thorough analysis of the fundamental psychological principles, we proposed a simple yet feasible solution that is also compatible with the current mechanical operation of the device. We propose to introduce an icon-indicator system in close proximity to the speed control chain.

While the system as a whole provides perceptual salience and discriminability to the pull chain controlling the speed states, the icons could instantly convey to the user knowledge about the availability of the three-speed variations with the indicator pointing to the current speed state. This system will not only aid the user to make decisions but also it will provide the user with instant feedback on their action.

The given psychological principles are vast and require a much deeper understanding to endorse any one solution as the optimum solution. We believe that a much deeper study with a significantly larger population should be conducted on the ergonomic design of the ceiling fan to come up with even more innovative solutions.

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