IASDR07
INTERNATIONAL ASSOCIATION OF SOCIETIES OF DESIGN RESEARCH THE HONG KONG POLYTECHNIC UNIVERSITY 12TH TO 15TH NOVEMBER 2007

DESIGNING A HAND DRYER: HYGIENE AND COMPARATIVE HAND DRYING SYSTEMS

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(Key Words: Hand-drying, Drying-methods, Hot-Air Hand-Drying Systems)

ABSTRACT

There is a strong perception that hand drying is an important step in hand washing and in particular, the sanitization process. The next generation of manual, semi automatic and automatic hand drying systems will be heavily influenced by their capability to enhance personal hygiene. The purpose of this study is to develop an understanding of the historical and current research in the hygiene performance of comparative hand drying systems. This research is intended to translate and apply the results from various scientific studies into a product design context.

The paper reviews selected literature investigating various systems in terms of hygiene and includes comparisons between paper towel, reusable cloth towel and warm air systems. The review covers a period from 1969 (Davis) studying bacteria on hands after drying and hand washing through to 2005 (Yamamoto) comparing paper towel and warm air hand drying.

It is difficult to draw conclusions in a product design context, however drying time, air filtration, product hygiene and consideration of the holistic hand hygiene process should be of concern to design teams.

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BACKGROUND

Our design team intends to conduct research into the design of a new generation hand dryer. Typically, the outcome will be a synthesis of knowledge brought together in a novel or creative manner. In this case, our design research program will include an understanding of hygiene issues around hand dryers; developing a broad understanding of existing hand dryer products; establishing new technologies that may inform the drying process and new hand dryer design experiments. The purpose of this study is to develop an understanding of the historical and current research in the hygiene performance of comparative hand drying systems. This research is intended to translate and apply the results from various scientific studies into a product design context.

METHOD

The paper reviews selected literature investigating the effectiveness of various hand-drying systems, with particular reference to the issue of personal hygiene. The reviewed research includes comparative studies between paper towel, reusable cloth towel and warm air systems. The review covers a period from 1969 (Davis *et al.*) studying bacteria on hands after drying and hand washing, through to 2005 (Yamamoto *et al.*), comparing paper towel and warm air hand drying.

LITERATURE REVIEW

There is a widespread belief that hand drying constitutes an important step in the hand-washing process, and in particular, the sanitisation process. Disease transmission is recognised as being facilitated by skin-to-skin contact, and hand hygiene is seen as being essential in the prevention of disease transmission, particularly in high-risk areas such as food preparation areas and clinical/medical environments.

A number of studies have been conducted over the last fours decades to investigate the effectiveness of hand drying systems in the context of skin hygiene. The majority of these studies have concentrated on clinical and food science scenarios, and it is uncertain whether the stringent standards of hygiene required by these circumstances are equivalent to those required in general non-domestic situations, such as the use of a public washroom. Nonetheless, the data collected by these studies provide valuable insight into hygiene practices, and will provide a better understanding of the limitations of the various hand-drying mechanisms currently available.

With a strong focus on microbiological factors, most existing research on hand drying systems assumes that effective hand washing and drying should result in a quantitative reduction of micro-organisms on a subject's hands. However, the results obtained by separate studies are clearly disparate, and subsequent conclusions are at times contradictory.

Early research by Davis *et al* (1969) investigated the qualitative and quantitative effects of hand washing and drying on the types and numbers of bacteria left on hands. Subjects were required to wash their hands by a standard method, and subsequently employ one of four different drying methods. These included (a) drying with an individual linen hand towels for 11 seconds; (b) drying with a fresh portion of continuous linen towel for 10 seconds; (c) drying with two paper towels, 8 seconds for the first, and 6 seconds with the subsequent towel; and (d) drying with a combination of paper towel (8 seconds), followed by hot air drying (9 seconds). Following bacterial analysis of subjects' hands, Davis found that there were no appreciable differences between the four methods. Citing that frequent and thorough washing with soap and hot water was critical to effective hand washing, Davis concluded that the choice of drying method was immaterial with respect to hygiene.

More recent studies (Meers & Leong,1989; Taylor *et al*, 2000; Gustafson et al, 2000) similarly concluded that there were no significant differences between use of paper towel, cloth towel and hot air hand drying systems. In their research, Meers and Leong allowed subjects to dry their hands under a hot-air dryer for 45 seconds, and subsequently declared that hot air hand drying was a suitable means of hand drying, and that there was 'no bacteriological reason to exclude them from clinical areas'.

In contrast, there are numerous research studies advocating that, from a microbiological perspective, the use of hot air hand dryers is inferior to other hand drying methods. (Blackmore & Prisk, 1984; Blackmore, 1989; Knights *et al.*, 1993; Redway *et al.*, 1994).

Believing that hand drying must meet two key requirements, '(a) the efficient removal of bacteria, and (b) the prevention of transmission of bacteria to others', Blackmore & Prisk (1984) demonstrated that hot air hand drying resulted in only 9% removal of bacteria, while cotton and paper towels showed 68% and 55% reduction in bacteria respectively. Following an initial bacterial sample taken from the right palm, subjects were required to dip their hands in 1 litre of sterile water, and then dry them using one of the three drying procedures. After drying, a sample was again taken from the right palm, and the bacteria plated and incubated for 48 hours.

Based on their results, Blackmore and Prisk concluded that drying with a hot air dryer does not act to remove or reduce bacteria, and has the potential to increase bacterial numbers if bacteria is contained in the hot air current. By comparison, the use of towels – either cotton or paper – are believed to physically remove bacteria with water as hands are wiped, and if a towel is clean or unused, should not reinfect hands during its use.

In recognition of the potential for aerosol contamination – the reinfection of hands through the bacteria liberated in the air during the drying process – Matthews and Newsom (1987) examined the bacterial aerosols released from hands during hot air dryer use, compared with those released by paper towels. Impression plates – hand imprints on agar plates after drying – revealed that similar numbers of bacteria were present in the hands after drying by either method, and that hot air hand dryers appear safe from a bacteriological viewpoint. In the first instance, Matthews and Newsom's research contradicts that of Blackmore and Prisk, however it should be noted that the experiments were conducted in a laboratory safety cabinet using filtered air, and it could be argued that that this does not accurately reflect a natural washroom environment.

In a later study, Blackmore (1989) builds on earlier research to assert that the dryer draws bacteria-rich air from its surrounding environment, and subsequently blows the bacteria out over the user, resulting in an increase in bacterial numbers on a person's hands. Suggesting that the relatively high humidity in washrooms provides a suitable environment for bacterial growth, Blackmore argues that not only are bacteria recirculated by the dryer's air currents, but that they can also be found inside the outlet nozzle. The comparative study included a laboratory analysis of the number of bacteria remaining of hands after drying with three models of warm air dryers, cotton towel and paper towel. In addition, the study conducted a survey of warm air hand dryers in 48 public washrooms, with the purpose of obtaining in situ data about dryer cycle times, exhaust air temperature, and humidity of the area surrounding the dryer, as well as confirming the presence of bacteria in dryer air streams and on the inside of the dryer outlet nozzle.

The results of the comparative study (paper towel *vs* cloth towel *vs* warm air dryer) confirmed Blackmore's hypothesis that warm air dryers increase bacterial numbers, with a 162% increase in numbers after drying with a warm air hand dryer, compared with 29% and 26% decreases in bacterial numbers when using paper towels and continuous cotton towels respectively. An analysis of the three different hand dryer models revealed variations in bacterial counts between the different models, however each of

the dryers consistently resulted in significant increases (between 136% and 187%) in bacterial numbers. The results from the survey of dryers in both male and female washrooms in public houses revealed that bacteria could be cultivated from swabs collected from both the air stream and outlet nozzles, indicating that it is possible for bacterial to be blown out onto a person's hands.

Aside from her microbiological conclusions, which confirm previous findings, Blackmore also makes several additional observations. Firstly, the average temperature of the hot air is found to be 56°C, which is not high enough to cause bacterial death. The average cycle time of the various dryers was found to be 33 seconds – too short to kill bacteria, even if the exhaust temperature were increased. Lastly, Blackmore makes some interesting observations regarding the practicalities of dryer use in public areas. The short cycle time often means that more than one cycle is necessary to dry hands effectively. Also, with only one person able to use a dryer at any one time, people may grow impatient, and use alternative means of hand drying (clothes or handkerchief) or shake their hands to dry them, thereby increasing the risk of bacterial transfer, and defeating the purpose of hand washing.

In 1993, a team of researchers from the University of Westminster added to Blackmore's work on hand washing and drying habits under natural conditions. (Knights *et al*, 1993). The research found, as Blackmore did, that hot air drying increased bacterial counts on people's hands, whilst paper and cotton towels demonstrated greater efficiencies in reducing contamination between the fingers and on the finger tips. It was also found that bacteria-contaminated air was emitted into the surrounding environment whenever a machine was drying. The study observed that people rarely used hot air dryers long enough to ensure more than 55-65% dryness, and often completed the process by wiping their hands on clothing. They also found that women were more likely to apply makeup or comb their hair while their hands were still damp, creating the potential for bacterial cross contamination.

The following year, the University of Westminster team published a further study of bacterial types associated with different hand drying methods.(Redway et al, 1994) Bacterial analyses demonstrated, as did the Blackmore and Knights *et al* studies, that hot air dryers produced significant increases in bacteria (436%). More surprising, however, was the discovery that some of the bacteria isolated from swabs originated from the gut (enterobacteria), indicative of faecal contamination of hands. A further study of bacteria taken from 35 hot air dryers from 9 different locations (including hospitals, eating places, and railway stations) discovered that 100% of dryer nozzles contained staphylococci and micrococci bacteria (from hair or skin), while 63% contained at least 6 species of enterobacteria, indicating faecal contamination.

Redway's team suggested that the use of hot air dryers should be carefully considered on health grounds, concluding that hot air dryers have the potential for depositing pathogenic bacteria onto the hands and body, as well as being inhaled and distributed into the surrounding environment.

In contrast, a number of studies have provided more positive endorsements of the use of hot air hand dryers, arguing that hot air dryers are more effective at eliminating potentially pathogenic organisms. Using a complex 'fingerpad protocol', Ansari *et al.* (1991) undertook a comparative study of the efficiencies of paper, cloth and electric warm air drying in eliminating viruses and bacteria from washed hands. Following hand washing, the five fingerpads of one hand were inoculated with either a viral (rotavirus) or bacterial (E. coli) suspension. The thumb remained unwashed as the 'control', while the remaining four fingerpads were subjected to a combination of conditions, including four handwashing agents, two conditions (dried or undried), and for the dried finger pads, either dried for 10 seconds by one of three methods - paper towel, cloth towel, or air dried (using a warm air hand dryer). Generating 16 data sets for analysis, Ansari discovered that, irrespective of the hand-washing agent used, electric air drying produced the highest reduction in numbers of both viruses and bacteria, while cloth drying demonstrated the lowest.

Ansari suggests that 'the blowing of warm air may lead to an accelerated dehydration of the skin surface, thereby irreversibly affecting the viability of the organisms tested. Furthermore, warm air may penetrate all the crevices in the skin whereas absorbent towels may not reach such areas, even though the skin appears dry.'

A recent Japanese study by Yukiko Yamamoto (Yamamoto *et al*, 2005) went one step further in the investigation of warm air dryer efficiency, by examining the various behaviours that users engage in when using hand dryers. The study investigated the development of bacteria colonies on hands washed with bacterial soap, and then dried using warm air with and without ultraviolet light, while being rubbed or held stationary, or by paper towels. The results indicated that hands were more likely to show increased bacterial counts when hands were rubbed, as opposed to held stationary under the warm air current, and that ultraviolet light led to the detection of fewer bacterial colonies. A comparative analysis of the whole hand (palm and fingers) versus the fingertips, indicated that warm air was more successful in reducing bacteria on the whole hand, while paper towel led to a greater reduction of bacteria on the fingertips, but not the whole hand.

DISCUSSION

While the research is somewhat limited, there are some issues that arise repeatedly across various studies. One major point of consideration is the issue of consistency across dryer cycle times. Gustafson *et al.* (2000) make this point quite clearly in their research, whereby they identify a lack of consistency in drying across historical research. Some studies exposed their subjects to very short drying times (Davis et al, 1969), while other studies used drying times as long as one minute (Meers & Leong, 1989; Matthews & Newsom,1987). With such disparities in methods, it is difficult to compare results in a methodical and systematic manner. Yamamoto *et al.* (2005) tried to address this issue by analysing the difference in bacteria colonies at both 15 seconds, and 30 seconds, however further work is required to achieve greater consistencies. However, as Blackmore identified, practical factors should also be considered in this area in order to make a sound assessment. Public washrooms can be places of extreme congestion, and while a long drying cycle time may achieve high levels of hygiene, it is probably unlikely to be practical if there are queues waiting for dryer access. Thereby, any next-generation design specifications should not only address the issue of hygiene, but also take into account the pragmatic use of the technology within the given environment.

If people have an adverse perception of hand dryer capabilities based on factors other than hygiene, there is little point relying on data that focuses on this particular angle, as it is unlikely to change those perceptions.

What is clear from the literature review is that hand dryer research has changed little over the last 40 years. Microbiological issues still dominate the research. Perhaps it is time for research to shift in focus, paving the way to develop the next generation of hand dryers.

Although this paper has not reviewed warm air hand dryer products, it is worth noting the introduction of a relatively new range of hand dryers. These systems appear to address some of the issues raised including the prevention of hand rubbing, reduced cycle times and air filtration. At the time of writing, the authors could not locate relevant research publications for comment.

CONCLUSION

As highlighted earlier in this paper, little research has been conducted on the behavior of people in real-life washroom scenarios. With most research centering on clinical/medical environments, the outcomes and conclusions discussed in this paper are very much biased in the direction of extreme hygiene standards.

More research is required into the relationship between hand washing, hand drying and hygiene in everyday situations.

There appears to be little agreement regarding the relative efficiency of hand drying methods. While some researchers are firmly of the opinion that hot air dryers are of inferior efficiency when it comes to the issue of hygiene, others are of an equally firm opinion that they are a safe and efficient means of hand drying. It is difficult to draw conclusions in a product design context, however drying time, air filtration, product hygiene and consideration of the holistic hand hygiene process should be of concern to design teams.

REFERENCES

Ansari, S.A., Springthorpe, S.V., Sattar, S.A., Tostowaryk, W. and Well, G.A. (1991) Comparison of cloth, paper and warm air drying in eliminating viruses and bacteria from washed hands. *American Journal of Infection Control* 19,243-249.

Blackmore, M.A. (1989) A comparison of hand drying methods. *Catering and Health* 1, 189-198.

Blackmore, M.A. (1987) Hand drying methods. *Nursing Times* 83(37), 71-74

Blackmore, M.A. and Prisk, E.M. (1984) Is hot air hygienic? *Home Economist* 4, 14-15.

Davis, J.G., Blake, J.R., White, D.S., Woodall, C.M. (1969) The types and numbers of bacteria left on hands after normal washing and drying by various methods. *Medical Officer* 116, 235-238

Gustafson D.R., Vetter E.A., Larson D.R., Ilstrup D.M., Maker M.D., Thompson R.l. and Cockerill F.R. (2000) Effects of 4 hand-drying methods for removing bacteria from washed hands: a randomized trial. *Mayo Clinic Proceedings* 75(7), 705-708.

Knights, B., Evans, C., Barrass, S. and McHardy, B. (1993) Hand Drying; Assessment of Efficiency and Hygiene of Different Methods. Survey by The Applied Ecology Research Group at the University of Westminister, London.

Matthews, J.A. and Newsom, S.W.B. (1987) Hot air electric driers compared with paper towels for the potential spread of airborne bacteria. *Journal of Hospital Infection* 9, 85-88.

Meers, P.D. and Leong, K.Y. (1989) Letters to the editor. *Journal of Hospital Infection* 14, 169-181.

Patrick, D.R., Findon, G. and Miller, T.E. (1997) Residual moisture determines the level of touch contact associated bacterial transfer following handwashing. *Epidemiology and Infection* 119, 319-325.

Redway, K., Knights, B., Bozoky, Z., Theobald, A. and Hardcastle, S. (1994) Hand drying: a study of \ bacterial types associated with different hand drying methods and with hot air dryers. Applied Ecology research Group. University of Westminster: London W1M 8JS

Taylor, J.H., Brown, K.L., Toivenen, J., and Holah, J.T (2000) A microbiological evaluation of warm air hand driers with respect to hand hygiene and the washroom environment. *Journal of Applied Microbiology* 89(6), 910-919.

Yamamoto, Y., Ugai K., and Takahashi, Y. (2005) Efficiency of hand drying for removing bacteria from washed hands: comparison of paper towel drying with warm air drying. *Infection Control Hospital Epidemiology* 26(3), 316-320