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Design strategies for mitigating passenger door holding behavior on suburban trains in Paris.

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Abstract

The length of time a train is halted at a station is particularly important during service peak periods and short headways. Some passenger behaviors, such as the deliberate holding open of doors, has a detrimental effect upon maintaining short dwell times and service timetable. Mechanical malfunction due to door holding is also a significant contributor to trains having to be removed from service.

There is a general absence of literature in the transportation field examining this problem or offering potential solutions. This paper discusses a commissioned research project carried out by Monash University's Department of Design for the French National Railway (SNCF). The method for this research drew upon techniques from other related disciplines to aid in the formulation of a design strategy to mitigate passenger door holding behavior.

Leveraging the physical design of the environment to provoke desired behaviors in people is a technique widely used in various disciplines from large architectural projects to more subtle uses of applied psychology. This paper describes the background to the problem as it manifests itself on SNCF's network in the Ile-de-France and discusses potential design solutions that may have pertinence for other networks similarly afflicted around the world.

1. Background

The length of time that a train is halted at a station is made up from multiple variables, such as the time it takes for doors to open and close, number of passengers alighting, boarding and passing through amongst others. The importance of measuring this 'dwell time' with some accuracy is in the formulation of timetables and the development of train services. However amongst the unpredictable incidences that can occur while a train is stopped is the interference to door closure by passengers. The deliberate holding of doors delays the train from getting underway and doors that have been held open for extended periods can have their closing actuators burned out. This renders the carriage inoperative for carrying passengers and is cause for the removal of the whole train from service.

While customer annoyance at malevolently delayed trains is clear, passenger attitudes to the implications of holding doors are mixed. Since most regular passengers find themselves at some point holding train doors, often with the best of intentions, the effects are not perceived as onerous. According to one New York Internet 'blogger' (Chan 2009) door holding as an anti-social behavior on trains was rated on a personal scale of 1 to 10 as only a 2. Yet despite this, research carried out in New York Metropolitan Transport Authority (Rivera 2008) identified six causes of train delay in which the holding of doors was the second highest source of impediment after track work.

There appears to be no body of academic literature reporting upon this phenomenon. This research is therefore drawn tangentially from a wide range of related sources such as Internet 'blogs' from passenger user groups and material from the French National Railway's (Société Nationale des Chemins de fer Français - SNCF) own department concerned with passenger security (Direction de la Surété – Stratégie et Observatoire). The Transport Cooperative Research Program in the United States (an affiliate of the Transport Research Board) does run and organize a database that seeks to collate and analyze mechanical failures in doors. The purpose of this database is to make available to other rail operators a shared repository of knowledge. This database does not examine the holding of doors per se, however does support the New York MTA data that door failures on American trains account for the single biggest cause of disruption to rail transit services after track work.

SNCF's own research in the Ile-de-France describes the following reasons for passengers holding doors;

1. The train is full (or the vestibule immediately adjacent to the door is blocked) and patrons exterior to the train still try to gain access by squeezing into the carriage while the door is closing on them. An individual restrains the doors from closing so that the arrangement of people within the vestibule can be changed to accommodate the boarding passenger.
2. The doors are held by a passenger within the train to assist a late approaching passenger to get on board. This action appears, from passenger user group websites to appear as an act of courtesy and assistance to a fellow passenger rather than an action that could damage the train, or prolong the journey. The urge to provide assistance to persons with prams arriving at the platform late and attempting to board is hard for passengers to resist
3. The train vestibule is clear but a person with reduced mobility (PRM) is being assisted to board and once again the holding of the doors is seen as an act of courtesy rather than something anti-social.
4. Doors are held by someone smoking so that they can evacuate the smoke from the carriage.
5. Doors held by skylarking behavior to deliberately detain the train. As in point 4 the central act is of defiance. The individual sees themselves as able to impose their will to determine the actions of others. (Patrick Alexa, SNCF 2009).

SNCF as with most rail networks around the world use audible alarms to alert passengers to the impending closure of the train doors. They have also, during 2009, employed staff to patrol platforms (at the busier stations) and 'police' the door closing process. In 2009 SNCF embarked upon a publicity campaign producing posters and flyers targeted at creating awareness amongst passengers that holding doors was detrimental to the service and their fellow patrons (Figure 1 overleaf). Studies show (Silver and Braun 1999) that the presence or absence of warnings can influence behavior. However at the time of writing it is unclear that this particular campaign has met with any noticeable decline in the instances of door holding, or as it is feared, that as soon as the publicity is over the behavior returns.

During the second half of 2009 SNCF's Direction de l'innovation et de la recherché (Directorate for Innovation and Research) commissioned research from Monash University's Department of Design to investigate ways of mitigating door holding behavior. The aim of

this study was to consider the design of the doors themselves and put forward concepts for future consideration. The research and design process took place over three stages;

1. An analysis of the various configurations of train door interface and their action.

2. An examination of literature from other fields of research most notably an investigation into ‘door gestures’ and environmental crime protection. This work tried to determine a best practice in encouraging behavior change through the design of the physical environment.

3. The advancing of new design alternatives as a response to the insights afforded by research outlined in stage 2.

Figure 1: SNCF’s public awareness campaign during 2009. “If you like trains on time. Do not delay”

2. Current train door configurations.

The research began by determining a typology of the door actions currently in use on the network and analyzing the manner in which passengers were holding them. There are essentially three types of door closing actions, from which a number of derivations exist. These door actions are *sliding, plug,* and *folding*;

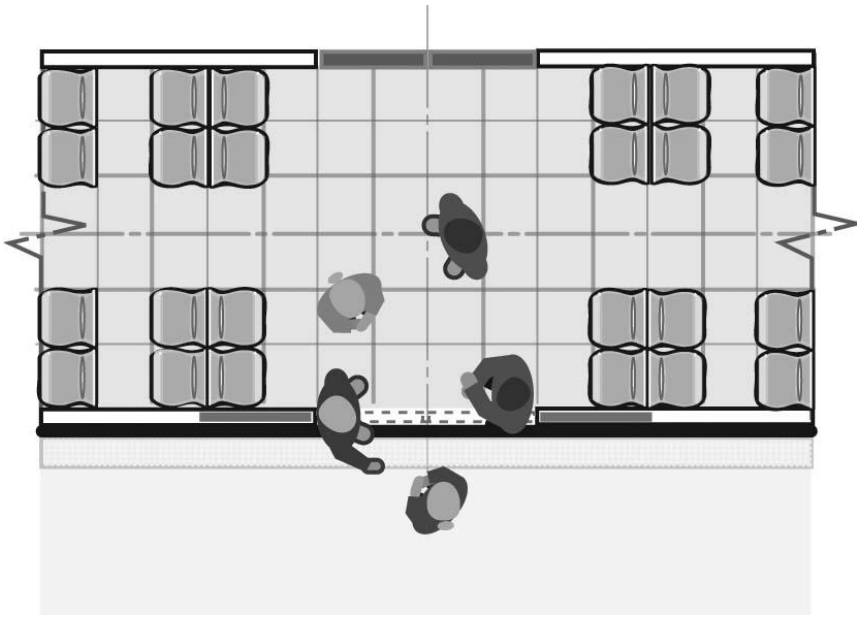
2.1 Sliding doors retracting into the carriage wall.

Door action: - As the name suggests, the door slides along a track that guides the path of the door as it is opened and closed. The speed can be varied and occasionally the trajectory by deviating the guide path slightly.

Advantages: - Sliding doors that retract within the body of the train wall do not intrude into passenger space, except when crossing the threshold of the vestibule. Their action is

relatively simple mechanically and quick since they have only a backward and forward direction of movement. Networks with short headways between trains prefer faster opening and closing doors since it contributes to shortening the dwell time at a station.

Figure 2: Holding sliding doors into the wall cavity



Disadvantages: - Sliding into a pocket in the wall often means that a dark area with no windows is created inside the accommodation adjacent to the doors. Some systems ignore 'hiding' the door in a pocket and continue to install windows in both the door and the retract space. This can look unsightly especially when an accumulation of dirt builds up that is consequently difficult to remove.

Effect upon door holding behavior: - Based upon SNCF's own observational data, sliding doors are the easiest to hold open since their trajectory is predictable by observing both door and the track in the floor. When open it is possible for a passenger to lean back against the door pocket and block the door's path. Since the door will have no velocity in this situation the weight of a person is sufficient to hold it. This action puts great strain on the door actuators and will ultimately burn them out, creating a defective door, and likely take the train out of operation.

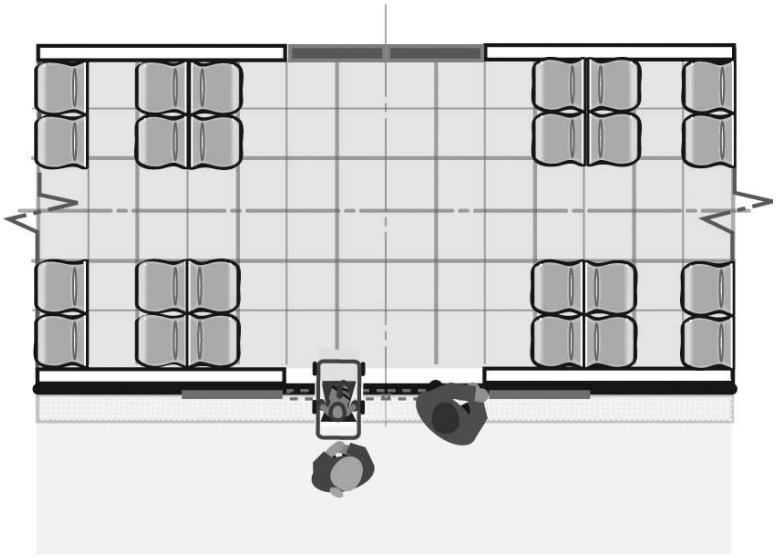
2.2 Sliding doors external to carriage wall.

Door action: - A derivation of siding doors that also have a track led uni-directional action. However in this instance the door is external to the wall of the train. Therefore the doors are always visible open or closed. (Figure 3 – overleaf).

Advantages: - Exposure to the exterior of the carriage means that access for maintenance is easier. No deadlight spaces are caused immediately adjacent to each door and it is possible to run windows all the way along the side of the train.

Disadvantages: - Sliding along a single-track trajectory impacts upon how the design of the exterior of the train is handled. The trailing edge of the door protrudes from the exterior of train requiring more elaborate sealing from weather elements.

Figure 3: Sliding doors external to carriage wall.

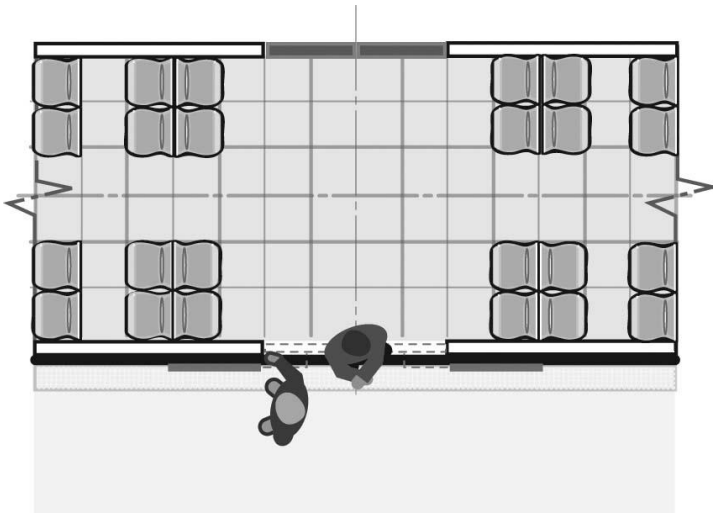


Effect upon door holding behavior: - SNCF data suggests that the trajectory of the door is easy to read and with the door exposed along the side of the train more ‘purchase’ is possible using arms and hands to hold the door from closing.

2.3 Plug doors

Action: - Like external sliding doors they retract along the exterior of the train. However as the edge of the doors meet at the mid-point they move into the threshold closing off the edge of the door flush with the exterior of the carriage, effectively ‘plugging’ the door aperture. Sometimes these actions are subtle deviations from a sliding door and sometimes the ‘plug’ action has some drama making the door appear as though it has changed trajectory dramatically.

Figure 4: Plug door action.



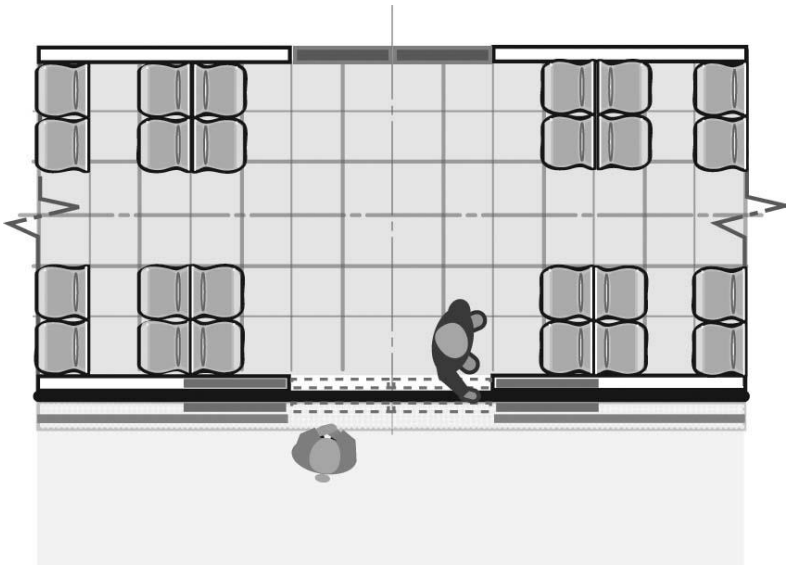
Advantages: - A plug door negates the crudity of a sliding door that is hung externally to the train and simply closes in the same plane. Doors that slide across the exterior of the train and seal themselves into the door aperture are popular on high-speed main line networks where the train’s aerodynamics are important, the Shinkansen in Japan is an example.

Disadvantages: - More complex mechanically, with issues therein on cost and maintenance, but they also take more time to close effecting dwell times on short headway services.

Effect upon door holding behavior: - SNCF do not report any data for these doors although anecdotally suggest that the double action of the plug door while not removing all predictability causes an adjustment in the passengers stance and makes holding the door a little more difficult. The wider or more dramatic the door trajectory from the side of the train into the vestibule threshold the greater the velocity and force the door is able to build up. This has the potential of attempting to impede the door more onerous.

2.4 Platform edge doors.

Figure 5: Platform edge doors (PED's)



Door Action: - Platform edge doors are sliding doors that make up a barrier along the platform. Trains (Paris Metro but not SNCF lines) are usually driverless so that stopping in exact alignment with these platform doors is consistent to actuate opening.

Advantages: - Security and safety. Platform edge doors negate either accidental or deliberate passenger falls into the track pit.

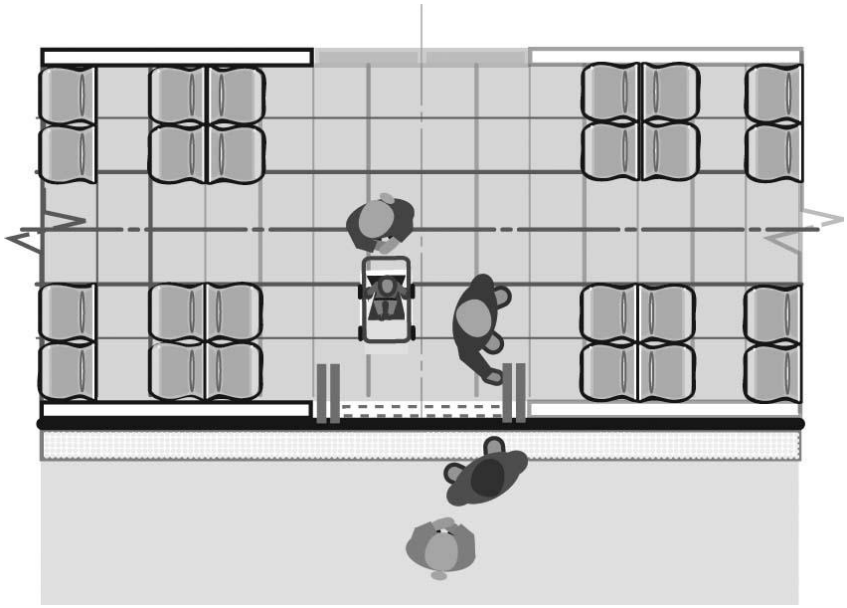
Disadvantages: - Slower dwell times, enormous expense on installation and they require consistent stopping positions. Networks with variable train stock designs and therefore door positions are inoperable with PED's.

Effect upon door holding behavior: - SNCF do not run trains in the Ile-de-France with PED's. Observations of the Paris Metro system does provide some insight. PED's are in effect two sets of sliding doors which increases the effective width of the threshold. A passenger attempting to hold the doors will need to straddle from the platform into the carriage vestibule If the platform side door is slightly out of alignment then the holding of the nosing rubbers along the leading edge becomes progressively more difficult. Equally the doors tend to 'set off' at slightly different times again making holding more of an effort and less predictable.

2.5. Bi-fold doors.

Door Action: - An uncommon door action on trains more prevalent to older busses and trams. However some older rolling stock around the globe contain examples (e.g. Regional services in the North of England). To accommodate the fold, pockets are created making the door fold back into the vestibule interior.

Figure 6: Bi-Fold doors



Advantages: - The door action is dynamic in two planes, therefore possibly giving a more complex perception of its trajectory. This could make the door harder to hold. Certainly on bus applications the folding action is very quick giving little time for a passenger in the vicinity to react unless actually caught between the nosing rubbers.

Effect upon door holding behavior: - Since this type of door is now relatively rare the authors' can only speculate upon how the door is perceived and held open. On busses folding wing doors are more likely to interfere with a standing passenger in the 'sentry' position (i.e. either side of the door) rather than be actively held for alighting. Since they have bi-directional movement the door tends to have a thin wall section.

The authors have identified five types of door. Analysis provided by SNCF's researchers determined the relative difficulty these doors might present to being held. The selection of these door types for various train designs is based upon variables determined during the original tendering process. Selection can be attributed to maintenance regimes, cost of manufacture and operational speed (to avoid long dwell times) but not, it would appear to avoid passenger door holding behavior. The authors therefore examined literature from other disciplines of research to discover potential insights into remedying this unwanted behavior.

3. Investigation into the literature of other disciplines

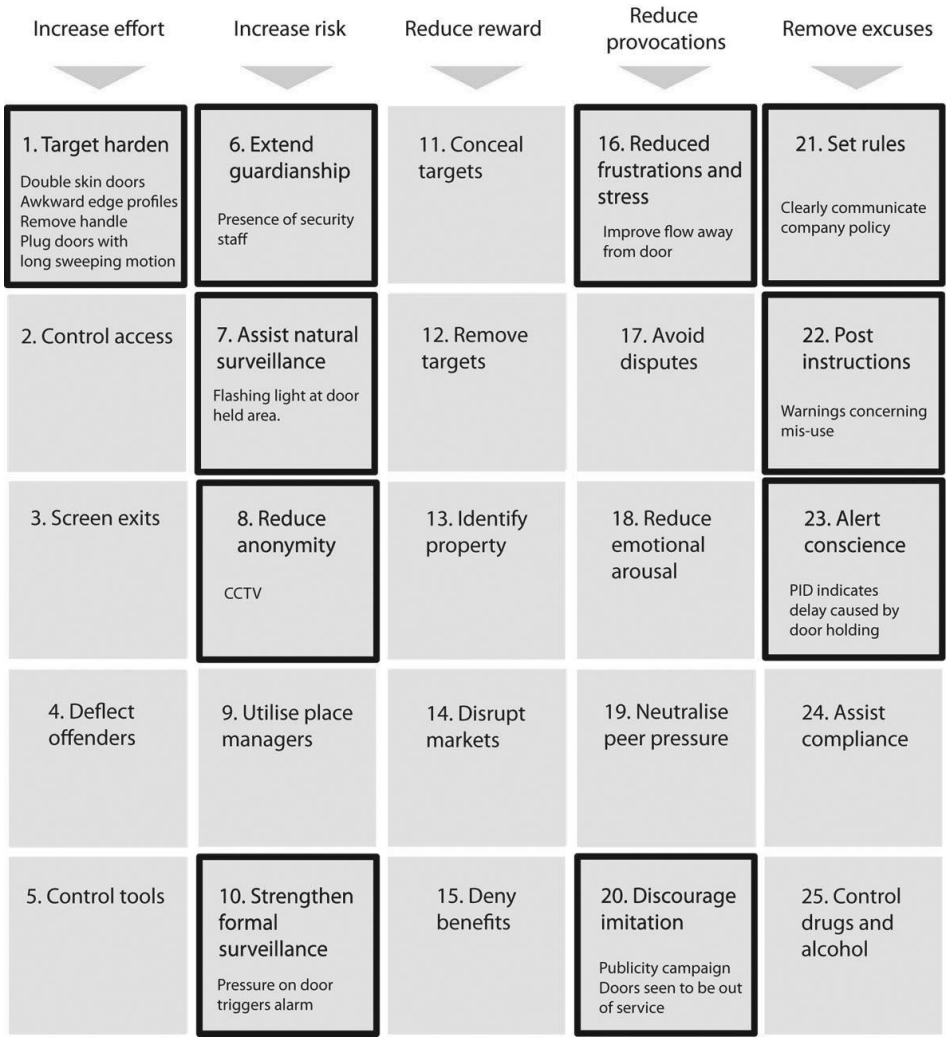
There is a wide body of material addressing the psychological motivations of general miscreant behavior (Colquhoun 2004, Osborne and Levis 1980). These studies suggest that the pre-requisites to an act of anti-social behavior are: -

- Motivation.
- Potential target opportunity or victim.
- Low risk. For example the scarcity of witnesses.

As observed from passenger user groups, many people do not see holding open a train door as particularly anti-social and certainly not a crime. Warning labels adjacent to doors do attempt to convey to the passenger that the incorrect use of the doors will delay the train. To better understand human motivations some researchers have examined the effects of the environment. Cornish and Clarke (2005) created a table of twenty-five situational responses

to anti-social and criminal behaviors known as 'analytical crime prevention' (Figure 7). The twenty-five situational responses are categorized under five key strategies; increase effort, increase risk, reduce the reward, reduce provocations and remove excuses. In terms of mitigating door-holding behavior the authors have highlighted ten of these strategies as having the most potential application (shown in black lined boxes).

Figure 7: Analytical crime prevention (Cornish and Clarke 2005)



Each strategy in essence attempts the following;

1. Increase the effort - Target harden – make it more difficult to commit the behavior and deflect the perpetrators interests.
2. Increase the risk – Surveillance takes away the lack of anonymity perhaps reinforced by alarms.
3. Reduce the reward – Legislate to put heavy fines in place.
4. Reduce the provocation – Reduce stress (providing information about trains timetable headways even where there might be space on the train in advance of it's arrival. Neutralize peer pressure and discourage imitation.
5. Reduce the excuse. – Clearly articulated instructions assist compliance and police behavior.

Examination of the key literature in human behavior and motivation in relation to acts of anti-social behavior has revealed strategies that might when applied underpin the design of a train door. Some strategies such as legislating for penalties or the general reduction of stress could be seen to be too vague. Therefore the research next focused upon the doors themselves and examined the nature of their movement in terms of gestures and particularly how passengers might interpret this.

4. Analysis of the door interface

From the observations by SNCF researchers of door holding behavior as discussed in section 1 and the analysis of the door configurations discussed in section 2 the authors would suggest that the interpretation of the door movement by the passenger determines the confidence to which that passenger might attempt to hold back the door. There is no body of academic literature concerning the human interface with train doors however work undertaken at University of Berkeley California (Ju and Takayama 2009) sought to investigate the capacity of doors in public spaces to create what humans would interpret as 'gestures'. The research determined that the interface of the door has three components; -

- Functional. The door opens and closes.
- Explicit. Graphical devices and symbols applied to the door to imply meaning, e.g. no entry, automatic or a brand etc.
- Implicit. This is where most of the gesture is created within the dynamic action of the door. Does it slide, swing out etc. Importantly the gesture of the door movement also embodies a trajectory and speed.

In their practical experiment the Berkeley research team filmed individuals as they approached a door to a public building. The door was operated to a range of movement criteria. After the encounter the individuals that used or passed by the door were asked to comment on their interpretation of the door movement as a gesture, such as friendly, welcoming, hostile etc. The interesting outcome of this research is that respondents did suggest that a doors movement could be interpreted as cognitive or that there was a gesture implicit in the action of the door. From the perspective of designers of train doors the idea of expressing intent to stimulate desired passenger behaviors is appealing.

Omitted from the Berkeley study were the implications of touch. Since in holding the train doors passengers clearly 'feel' a physical contact with the material, the authors would consider the addition of tactility to any door interface. By examining the notion of the door interface as inherently gestural and combining this idea with those behavioral interventions outlined by Cornish and Clarke (2005) the authors entered the final phase of the research in the creation of new door designs. These designs where produced as a series of illustrations depicting various stages of the door in operation.

5. Design outcomes

Four design concepts are discussed in this section of the paper. Each design attempts to leverage key deterrence strategies as described by Cornish and Clarke with gesture and graphical reinforcement to solicit the desired behavior.

5.1 Door concept 1.

Door Concept 1 (shown in figure 8): - a plug door with an internal sliding edge to close off the last 40cms.

Opening: - The initial action of the door is to move away from the vestibule threshold and in a second movement glide along the wall of the train.

Closing: - (shown in figure 9): - The door moves quickly back across the threshold slowing at the last moment to allow internal sliding doors, marked with yellow and black diagonals, to close the gap before the remainder of the door plugs into place.

Figure 8: Door concept 1 in the fully open position

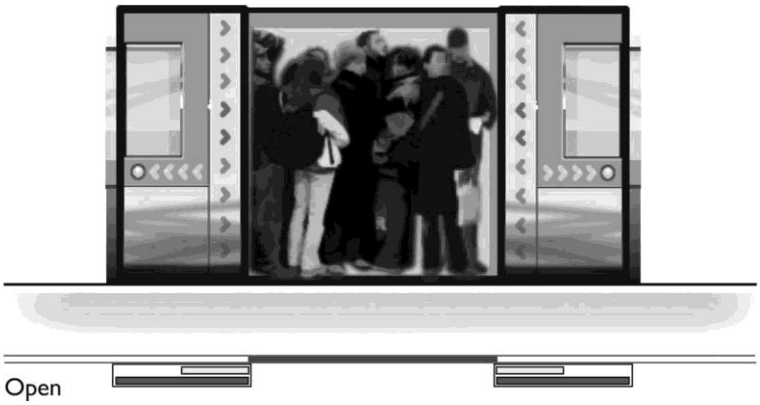


Figure 9: - Door concept 1 at the midpoint of closing

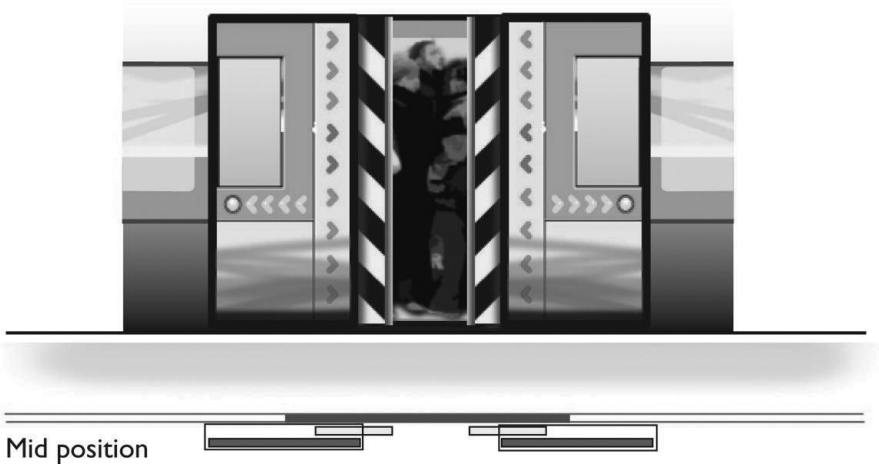
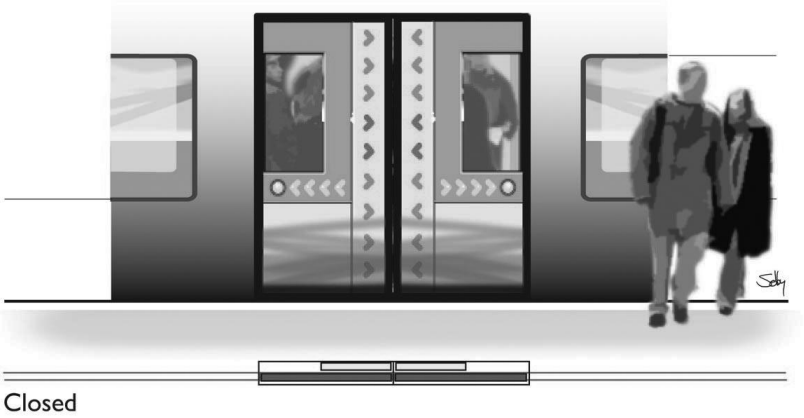


Figure 10: Door concept 1 closed



Intended strategy to deter holding: -

1. Target hardening. The dual action attempts to convey a sense of cognition that the door is pushing people gently in or out of the train.
2. Graphical convention. The black and yellow diagonal markings are reminiscent of an industrial equipment guard in a factory. Thereby carrying a graphical ‘warning’.
3. Animated visual stimulus. Accompanying the doors is a red illuminated vertical chain of arrows that flash as the door is closing emphasizing the need to clear the reducing gap. Upon opening, the doors show a horizontal line of green arrows pulsing in the direction of the opening action to warn platform patrons to stand clear as the doors begin to part. Further graphical conventions to solicit desired behavior.
4. Reducing frustration. Improving flow across the threshold. The door opening actuators are located to the extremities of the door on each side. The advantage of this arrangement over existing doors is that platform passengers are maneuvered by access to the door actuator to place themselves in the optimum position to allow people to leave the train.

5.2 Door concept 2

Door concept 2 is based once again upon plug doors (Figure 11).

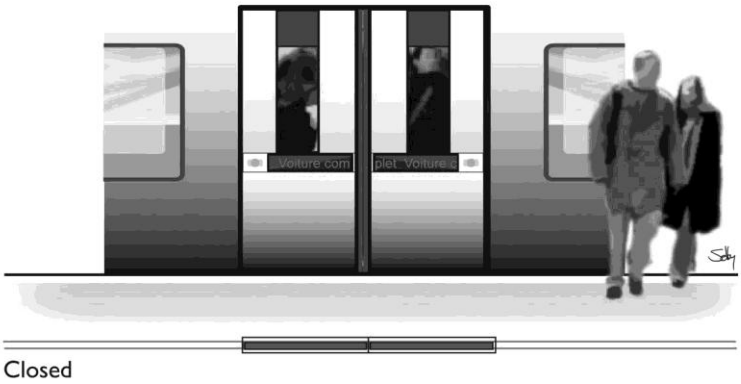
Figure 11: Door concept 2 in the fully open position

Intended strategy to deter holding: -

1. Motion graphics to attract attention. The passenger information display (PID) has been introduced to the sidewall of the door to indicate to patrons standing on the platform that the interior of the carriage is either full to capacity or occupied by people standing close to the door. Pressure sensors in the floor adjacent to the door detect the extent of crowding the intention is to encourage platform side passengers to move to another door.
2. Tactile response. The door nosing rubbers, which under pneumatic pressure will vibrate if blocked by an obstacle, such as a passenger, in any position other than in the fully closed interlock. The idea embodied in this action is to dissuade someone from holding the edge of door by introducing an uncomfortable sensation when the edges of the doors are touched.

Figure 12: Door concept 2 in the mid closing position

Figure 13: Door concept 2 in the closed position



5.4 Door concept 3

Door concept 3 (figure 14) contains three distinct strategies to deter holding behavior.

1. Encourage better passenger flow to reduce passenger frustrations. In essence the door is a standard sliding door into the wall cavity, however at the centre of the threshold a middle bi-fold door is located The position of the bi-fold when open forms an obstacle around which the passengers are required to move.

Figure 14: Door concept 3 fully open

2. Graphical instruction. The design is further enhanced by graphical indicators communicating that the passengers have to pass on the right side to enter the carriage and on the left of the carriage to exit. The entry button to the carriage is located on the right hand side further stimulating the correct path to enter. Upon closing the bi-fold flattens and sliding doors move across. For a patron holding these doors they will have to contend with them moving in two directions making the task more difficult.

Figure 15: Door concept 3 at the midpoint of closing

Figure 16: Door concept 3 closed

6. Conclusion

Train dwell time is an important determinant of network performance. Some of the variables that make up the total dwell time at a station are predictable but others are not. Passengers willfully holding doors delay departure and endanger putting trains out of service. This problem for the French national railway SNCF in the Ile-de-France is a particularly onerous one that has led the organization to direct resources toward public awareness campaigns and increasing platform staff at busy railway stations. A collaboration between Monash University's Department of Design and SNCF's Directorate of Innovation and Research has created a number of conceptual door designs that seek to mitigate the issue. SNCF believe that if passengers are deterred from holding back the train doors at stations then improvements can be made upon network schedules and a reduction in the number of trains removed from service.

Due to the lack of academic literature on this subject the research has drawn upon some specific aspects of human behavioral analysis to stimulate design innovation. The design studies responded to passenger behavior and motivation in such a way as to deter

malevolent actions. Although each of the designs offer a slightly different variation they all contain the same essential themes; -

- Make the undesired behavior more difficult to action. Double action door movements to make retention of the door after it has started to move harder.
- Bold visual stimulus that reinforces traditional sound based warnings with illuminated warnings.
- The use of touch to create mild discomfort to the perpetrators hand or shoulder pushing against the door.
- Encourage superior passenger flow over the door threshold by positioning door actuator buttons to the outside of the door on the exterior of the train and the centre of the door on the interior of the carriage.

The differences in the concepts concern the extent to which the above characteristics have been exploited;

Concept 1 makes the most of graphical elements such as illuminated arrows and the imposition of a secondary sliding door again with high visual impact.

Concept 2 tries to improve upon the previous design by combining both a window and an illuminated display. The sliding internal door is removed and instead the nosing rubbers are pressurized to vibrate as they close upon an obstacle.

Concept 3 contrary to the previous design, uses an obstacle i.e. a central bi-fold door to stimulate passengers to flow across the threshold on one side or the other to improve accessibility. Door holding itself is mitigated once again by the use of dual door actions, sliding and folding to make the positioning the body across the threshold more onerous.

Doors with multiple actions such as the ones proffered as concepts are also slower to close than simple sliding doors, which is a factor considered in the design of trains designated for a frequent service. Without building the doors and running some sort of simulation the performance of these concepts can only be speculated. However the Authors suggest that the relative slowness of the door closure mechanism might be compensated by the reduction or removal of delays caused by passengers blocking the doors. This remains to be modeled. Equally further research is needed to determine the cost benefit of maintaining mechanically complex door actions (especially internal sliding doors) against the cost of disrupted timetables and defective trains put out of service.

Research into behavior often reveals the adaptability of human beings and that over time what was once novel will become familiar. Door actions will be become ‘learned’ and that new ways to disrupt door closing may emerge. Public consciousness to the problem needs to be maintained (Patrick Alexa, SNCF 2009) which is why a policy of publicity has been implemented on the network. Designers are therefore likely to be required to continue to respond to changing passenger behavior especially when it undermines respect for public infrastructure.

The work undertaken in this research project suggests that multiple strategies to mitigate door holding behavior needs to be employed and investigated. A design methodology analyzing and then conceptualizing the problem has enabled these disparate sites of knowledge to be brought together. However this is at early stage of investigation and further development of the design strategy and implementation of the outcomes remains to be modeled and developed.

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