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Identifying bottlenecks and designing ideas and solutions for improving aircraft passengers' experience during boarding and disembarking

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Abstract: Interferences during the boarding procedure are one of the main reasons of delay and increased turnaround time, becoming a relevant problem for airlines. Observations of the boarding process and questionnaires inside the aircraft revealed three main bottlenecks during the boarding process: (1) Hand luggage: Storage space is not sufficient and/or not used efficiently; (2) Preparation: Passengers are not well prepared for the boarding process; and (3) Communication: Audio announcements are unclear and unfocused. By translating these bottlenecks as possibilities for improvement, solutions were designed for the airport and aircraft interiors to reduce boarding time and improve the passenger boarding experience. Concepts ranged from an app to scan your hand luggage at home and make a reservation for overhead bin space; to a redesigned waiting area to help passengers prepare for boarding; to new boarding methods and redesigned aircraft seats. In this paper, several design concepts are presented in more detail.

Keywords: airplane boarding; passenger behaviour; boarding time reduction; hand luggage

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1 Introduction

Efficient boarding of aircrafts is critical to ensure short turn-around times, thereby also increasing the efficiency of flight schedules, since airplanes are able to make more flying hours per day (Steffen, 2008). Interferences during the boarding procedure are one of the main reasons of departure delays, thereby increasing the turn-around time, and leading to higher costs. Hence, passenger boarding is becoming a relevant problem for airline companies. Reduced boarding times might also affect passenger satisfaction; if waiting time and stress at the airport can be reduced, passenger experience can be improved.

Although a lot of research has been performed on the effectiveness of different boarding methods (Jaehn & Neumann, 2015), the focus of these studies is to optimize the time to get passengers into an airplane, as a process flow. Computer simulations indicate that there are more efficient boarding methods than those currently in use, for example the reverse pyramid method or Steffen method may be able to reduce boarding times (Qiang et al., 2014). However, practical challenges often occur when implementing such optimal boarding schemes (Steffen, 2008). For example, two-door boarding could significantly reduce boarding time but this is not possible if passengers are boarding via the jet way.

Furthermore, not all effective boarding strategies are passenger-friendly, since most boarding methods separate passengers that are travelling together (Ferrari & Nagel, 2005) This can negatively influence passenger experience, since about 50% of all aircraft passengers travel in groups (two or more persons) (Bazargan, 2011) and they do not like to be split up during the process. Next to that, the boarding method simulations are often performed in an ideal situation, and do not take into account actual passenger behaviour: although the ground handling, airport or airline staff mainly controls the turnaround processes, the aircraft boarding is driven by the passengers' experience and their willingness or ability to follow the proposed procedures (Schultz, 2018).

Two types of interference that impacts boarding time can be distinguished: seat interference (when passengers have to get out of their seat row to let another passenger pass) and aisle interference (when someone is blocking the aisle). Aisle interferences

are mainly caused by hand luggage storage (Coppens et al., 2018), while passengers sitting in the wrong seat can cause seat interferences.

Therefore, the goal of this study is twofold: 1) analyse actual passenger behaviour and measure the effect on comfort experience during the boarding process of an aircraft (at the gate as well as inside the aircraft); and 2) to design solutions for the airport and aircraft interiors that reduce boarding and disembarking time while at the same time improving the passenger boarding experience. The result consists of several ideas and concept design directions to serve as an inspiration and that need to be further developed.

2 Method

This paper summarizes the work of fifteen Industrial Design Engineering Master students from Delft University of Technology. In the first phase, the students have (in groups) analysed the main bottlenecks in current boarding behaviour of aircraft passengers using observations and/or questionnaires. Three groups of five students each have performed research studies for three different airlines: KLM Royal Dutch Airlines (flag carrying airline of the Netherlands), KLM Cityhopper (regional airline subsidiary of KLM), and Transavia (low-cost airline subsidiary of KLM). In the second phase, the students individually designed concepts in order to reduce boarding and disembarking time while at the same time improving the passenger boarding experience.

2.1 Observations

One of the student groups analysed the information provided to passengers at the gate. They did this at Amsterdam Schiphol Airport (AMS), the Netherlands, at gate B16 specifically. This is a self-boarding gate, meaning that passengers scan their own boarding pass, after which the gate opens to pass through in order to get to the airplane.

The other two student groups observed passenger boarding behaviour inside the aircraft, for two KLM flights (AMS-SVO; AMS-SAO) and three Transavia flights (AMS-PSA; AMS-BCN; BCN-AMS).

2.1.1 Information at the gate area

In order to analyse the adequacy and clearness of guidance provided by the airline to the passengers waiting to board through the gate, audio announcements were recorded with a sound recorder (model Roland R-09), from the start until the end of the boarding process (20 minutes on average). Recordings were made in the middle of the gate area (middle row, right in front of the boarding desk). The recordings were evaluated on the audibility and relevance of the information concerning passengers boarding through the specific gate B16. Visual communication of information, such as the digital information screens above the gate, was photographed and described.

2.1.1 Passenger behaviour inside the aircraft

Since filming was not allowed due to privacy restrictions, two student observers were assigned to a location inside the aircraft by the KLM purser (one at the front and one in the middle of the aircraft) during the boarding procedure. From their fixed location, one

of the observers took notes while the other observer completed a predefined template regarding causes of interference. Two different types of aircrafts were observed: one single-aisle Boeing 737 (AMS-SVO, 163 passengers) and one dual-aisle Boeing 777 (AMS-SAO, 387 passengers). These flights were selected since these are often hand luggage critical flights. The predefined template consisted of possible causes of delay with regards to hand luggage and time spent on it: weight of hand luggage, height of the overhead compartments, unprepared passengers, jackets (undressing), no available space, and relocating luggage.

Similarly, for the three Transavia flights, two student-observers were present inside the aircraft cabin before passengers started to board. Per flight, each student-observer noted the actions during boarding of all passengers and crew members interacting with or passing six rows of seats. The observations started when the first passengers started to board the aircraft and continued until pushback (airport procedure during which the aircraft is pushed back from the gate). The Transavia observations were focused on the interactions the passengers had with others (fellow passengers and crew) and the items they carried, before being fully seated. In addition, announcements and unexpected events were noted. When interactions or events caused a queue in the aisle, this was also noted. Pen, paper, and a list of abbreviations for predefined interactions were used to write down the observations.

2.2 Questionnaires

Questionnaires (in Dutch and English) were distributed inside the Transavia aircraft cabin, after take-off. Next to general questions about their nationality, gender, and age; purpose of their flight, the questionnaire asked passengers about their feeling and experience before and during the boarding process; and the complexities they experienced while boarding. Six variables were measured using a 5-point Likert scale: (1) Stress before boarding; (2) Stress during boarding; (3) Pace; (4) Experience; (5) Difficulty; (6) Expectations:

(1) How did you feel at the gate, before boarding? (1=No stress; 5=A lot of stress)
(2) How did you feel during boarding? (1=No stress; 5=A lot of stress)
(3) How did you experience the pace of boarding? (1=Very slow; 5=Very fast)
(4) How would you rate the experience of boarding? (1=Very negative; 5=Very positive)
(5) How would you rate the difficulty of boarding? (1=Very difficult; 5=Very easy)
(6) Did the boarding process go according to your expectations? (1=Not at all; 5=Very much)

The complexities (factors that make the boarding process complex) were measured using open questions. Data were processed using SPSS and Google Spreadsheets. Significance was accepted at $p<0.05$.

2.3 Design opportunities

The same group of 15 students have been asked to translate the bottle necks from the observations and questionnaire results into possibilities for improvement, and to design

solutions for the airport and aircraft interior that reduce boarding and disembarking time and improve the passenger boarding experience.

3 Results

3.1 Observations

3.1.1 Information at the gate area

Only 27% of the announcements (4 out of 15 on average) that could be heard at the gate were relevant to the passengers boarding via that gate. In the gate area, audio announcements are currently the main means of communication between airline and passengers; however, information is easily lost because of the loud background noise, and passengers that do not pay attention to the announcements.

From interviews with gate agents at the gate area at Amsterdam Schiphol Airport, it became clear that face-to-face communication is preferable when giving personalized and relevant information to individual passengers.

3.1.2 Passenger behaviour inside the aircraft

From the observations during the two KLM flights it became clear that the three factors that contribute most to increased boarding time are: rearranging personal items in the luggage (while in the aisle) (33%, average 50 sec delay for each occurrence); taking jackets and sweaters on or off (while in the aisle) (24%, average 45 sec delay); and relocating luggage in the overhead bins (8%, average 30 sec delay). A lot of passengers enter the aircraft unprepared and seem to decide what they want to have with them in the seat while standing in the aisle, thereby blocking the flow of passengers. Another conclusion is that the first boarding passengers caused immediate queuing. The first people to board seemed to take more time during boarding, possibly due to unawareness since the queue is forming behind them (out of sight).

For the three Transavia flights, the three main causes for the disruption of flow were: interacting with hand luggage (20.6%), interacting with fellow passengers (18.8%), and interacting with crew (13.3%). Furthermore, the sorting of luggage, such as sorting out personal items from a bag, also occurred often (12.4%). It was observed that passengers have discussions inside the aircraft while boarding, for example with fellow passengers on personal belongings (when relocating luggage). Another observation was that announcements about the luggage were not spread optimal over the boarding time. Passengers did not hear the announcement, because they were either still in the jet way or already seated.

3.2 Questionnaires

During the three different Transavia flights, in total 261 passengers (43% male, 56.2% female) aged 12 years and older (M=41.8 years, SD=18.1) completed the questionnaire. Passengers were mainly travelling for leisure (49%) and work (25%) purposes and there were responses from 25 different nationalities.

A paired samples t-test showed there was no significant difference in the scores for the Stress experienced before boarding (M=1.56, SD=0.90) and the Stress during boarding

(M=1.62, SD=0.91). Correlation tests showed that there was a weak negative relation between experienced Difficulty level and Stress before boarding (R=-0.237) and between Difficulty level and Stress during boarding (R=-0.226). A weak positive relation was found between Expectations and Difficulty (R=0.298). A moderate positive relation was found between Pace and Difficulty (R=0.325) and between Experience and Difficulty (R=0.487).

The three most important factors that make the boarding process complex are, according to the respondents: Luggage (16.3%), Fellow passengers (19%), and Queue formation (11.8%). These factors all lead to a disruption of the flow of passengers. For the factor Luggage, a lot of respondents (82.8%) made a remark that luggage does not fit due to earlier placed luggage, and that the overhead bins are too small for the amount of luggage that is taken by passengers inside the cabin.

3.3 Main bottlenecks during the boarding process

Three main bottlenecks have been defined on the basis of the results from the analysis of information at the gate area, observations of passenger behaviour inside the aircraft and questionnaires:

(1) Hand luggage: Storage space is not sufficient and/or this space is not used efficiently;

(2) Preparation: Passengers are not well prepared for the boarding process;

(3) Communication: Information provision, audio announcements in particular, is unclear and unfocused.

The students used these bottlenecks as a starting point for their design solutions.

4 Design solutions

The three main bottlenecks have been translated into design opportunities as a starting point for the ideation: (1) Make better use of available space for hand luggage (section 4.1); (2) Help passengers prepare for the boarding process (section 4.2); and (3) Use more focused and clear communication (section 4.3). Below, several ideas and design concepts are presented in more detail for each of these design opportunities.

4.1 Make better use of available space for hand luggage

The main cause of interferences and delay regarding the process of storing hand luggage during boarding seems to be that passengers are not prepared and are taking off jackets and rearranging personal items from their bags while standing in the aisle. Passengers lack awareness that they might be delaying the flight and might even cause greater delays if the aircraft misses the appointed time slot. One of the solutions is to make hand luggage storage more accessible during the boarding procedure for all passengers, for example by providing a close and clean storage to put personal belongings inside or near the seat, leaving more space in the overhead bins. The luggage can be distributed more efficiently by creating a feedback system for passengers and their luggage, e.g. by indicating free available space. Making it possible to reserve bin space might also

prevent discussions with crew or other passengers about personal belongings. Furthermore, in order to reduce the number of people blocking the aisle, a travel organizer was designed to help passengers sort out their luggage (items they need during the flight) by putting all personal items into one bag/compartment that can easily be taken out.,.

Another solution is to create an app for passengers to measure their hand luggage at home by taking a picture (see Figure 1). The passenger can receive feedback whether their luggage fits the maximum dimensions and is allowed on board by the airline, and whether it fits in the available bin space. For the airline, the additional advantage is a possible forecast of hand luggage that passengers will carry, and a possibility to take preventive measures in order to limit the amount of hand luggage (e.g. provide check-in for free).

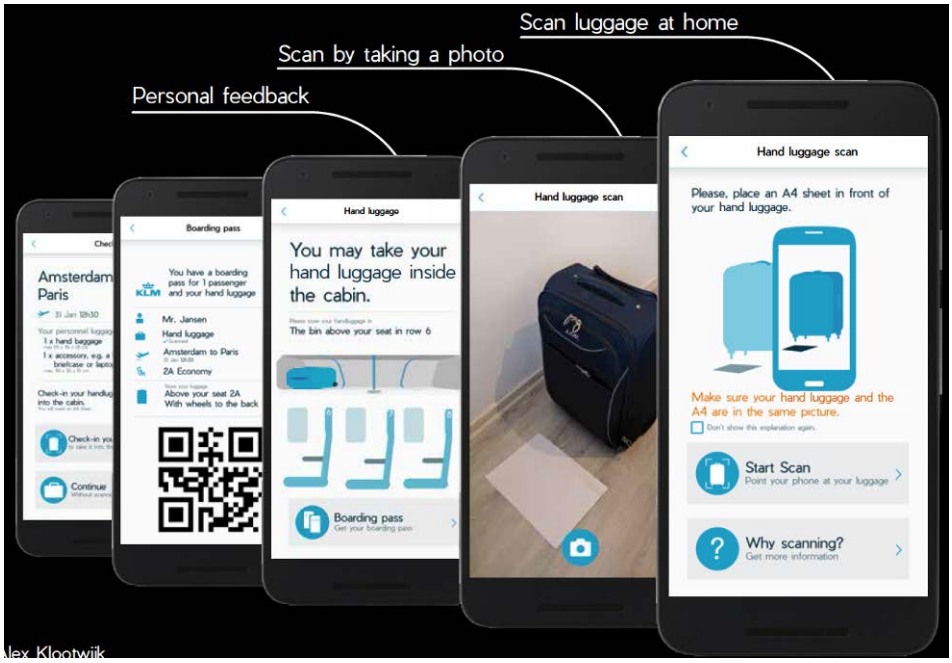

Figure 1. Scan hand luggage at home with an app to get direct feedback whether or not your luggage will fit inside the aircraft *(Klootwijk, 2017)*

4.2 Help passengers to prepare for the boarding process

In order to create a smooth boarding process, passengers should be made aware of the influence they have on a smooth boarding process and on-time departure. One of the options to help passengers prepare (and change their behaviour) is by making better use of visual communication means, such as the LCD screens at the gate. However, awareness and preparation is not only relevant at the gate, but also at home, while packing the luggage, or even already while booking the tickets (e.g. when booking hold luggage). A journey guidance app could give personalized information, for example by providing packing tips, and showing the boarding process with possible disturbances.

At the gate, passengers usually are in a waiting and relaxing mood. However, when getting closer to the plane, their attitude is changing from relaxed to hurried, and personal space is becoming increasingly compressed. Once inside the plane, the personal space is even more limited. Therefore, the ideal moment for passengers to be open to suggestions and communication is while they are still at the gate area. The

waiting time can be used as preparation time, and by projecting informative visualisations onto the floor at the gate area, passengers are encouraged to, for example, take off their jackets in advance, or take out the items they need during the flight (see Figure 2) already before boarding starts.

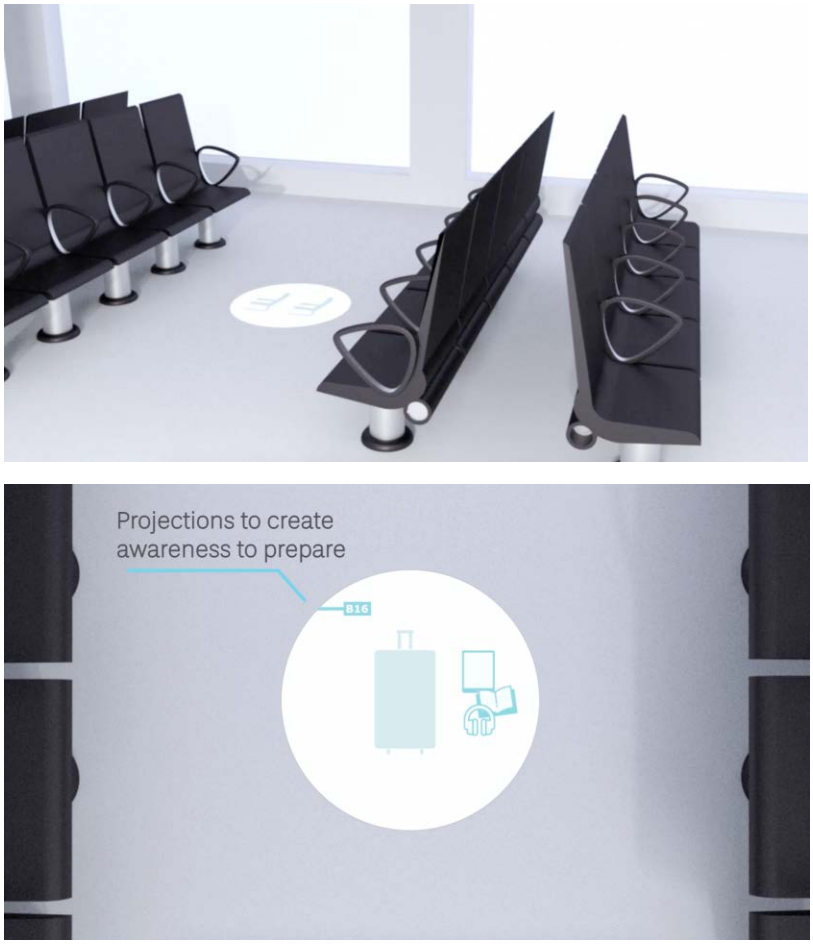

Figure 2. Information projection at the gate area to make passengers aware how to prepare for boarding *(Tezcan, 2017)*

4.3 Use more focused and clear communication

Opportunities for a more focused and clear communication with airline passengers are, for example, a personalised information feed, or showing an instruction video at the gate area on how to prepare/how to board. Reducing audio announcements to create a "silent airport" terminal can lead to a more pleasant waiting time and working environment for passengers and crew. In order to achieve this, other communication media should be applied, such as videos, or, more innovative: lighting. Using lighting as a means of communication is effortless for passengers. Lighting can be projected onto the floor so it catches attention when people are looking down onto their smartphones, and change when boarding gets closer. Strips of light can have a certain flow and direction, different for the different phases until boarding starts, to make passengers feel the urgency that they need to move and take action (see Figure 3). Due to the surprising

effect, it offers passengers a new experience and thereby might distract them from the waiting.

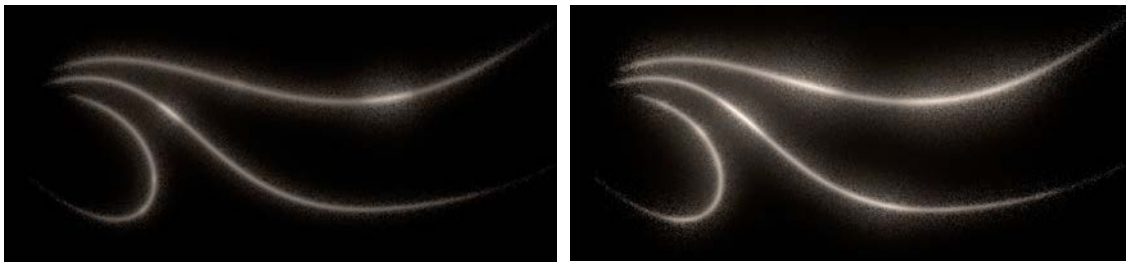

Figure 3. Lighting as a means of communicating urgency (time) and direction (flow) by pulsating movements *(Pettersson, 2017)*

5 Discussion

As observed during the KLM flights, the passengers first to board caused immediate queuing inside the aircraft. This seems to be in line with the findings of Steiner and Philipp (2009), who reported that a queue of waiting passengers forces a passenger to hurry, thereby decreasing the cabin time of a passenger.

From the questionnaire results of the Transavia passengers it seems that an increased stress level increases the experienced complexity of boarding. Complexity levels seem to decrease when boarding proceeds more according to passenger expectations. So, boarding complexity can be reduced when passengers know what to expect and when they experience less stress.

No significant differences were measured between the stress of passengers before boarding and during boarding. However, differences may exist between the actual experience and the memory of the experience (Kahneman et al., 1993), so it would be better to ask passengers about their experience during the different stages of the boarding process.

The results from the observations and questionnaires are in line with the study by Bouwens et al. (2017), who also showed that there is a need to improve passenger comfort during luggage stowage when boarding, since passengers reported the lowest comfort levels during this phase of the flight. A possible reason for this could be the uncertainty regarding space for the hand luggage.

Although the main bottleneck, hand luggage, is mentioned in other boarding research studies as well (e.g., Steiner and Philipp, 2009; Kierzkowski and Kisiel, 2017), the two other bottlenecks reported in this paper (Passenger preparation and Communication), are less reported.

Due to privacy concerns, observations at the gate and inside an aircraft were performed using pen and paper instead of video observations. Most observations were done in the back end of the aircraft, while most of the flow disruptions occurred in the front of the plane, which was not always clearly visible to the researchers.

The ideas and concepts presented in this paper seem promising, since a test with organizing hand luggage (Coppens et al., 2018) indicated that boarding time could be reduced by 2.5 minutes for 150 passengers. This is comparable to the findings of Steiner and Philipp (2009), who state that, based on observations and simulations for an Airbus

A321 type, a two to four minute reduction in boarding times could be achieved when passengers do not carry too many pieces (luggage, bags, jackets) that need to be put into the overhead bins. Milne and Kelly (2014) also suggested assigning passengers to seats in a way that their luggage was evenly distributed throughout the aircraft, whereas providing more space in the overhead bins is another way to improve boarding times (Kierzkowski and Kisiel, 2017).

Another example of a concept to improve the boarding experience is the personalised notification light by Akkerman (2016). This spotlight, located above the aircraft seat, becomes brighter when a passenger approaches their seat, using a Bluetooth connection with their mobile phone, for example. Research has shown that boarding time of passengers using the personalised notification light was, on average, two seconds per person shorter than standard way of boarding (Akkerman, 2016). For a full flight, this could mean a boarding time reduction of 5-7 minutes. The study by Van Hagen & Galetzka (2014) has shown that by providing a pleasant environment and other forms of distraction, the perceived waiting time at railway stations could be reduced. This principle might apply to the light projections as well.

Furthermore, general applicability of ideas and concepts should be evaluated, since it also became clear from the research performed in this study that every flight has its own specifics. The jacket interference (thick winter coats) and tax free shopping items, for example, are issues related to season and destination, whereas there were also hand luggage problems observed specifically for double-aisle aircrafts. Therefore, the ideas and concept design solutions presented in this paper are to be used as a source of inspiration, and further research is needed to investigate the feasibility of the concepts. Research is needed on how it is functioning in an actual operating environment (e.g. during flight/boarding process) and whether it indeed affects passenger experience in a positive way.

6 Conclusion

Observational research on actual passenger behaviour during aircraft boarding has revealed that three main bottlenecks are: hand luggage, lack of preparation (by passengers), and communication. In this paper, several ideas and design concepts have been presented in more detail, including an app to scan hand luggage at home, information projection at the gate area to make passengers aware on how to prepare for boarding, and using light as a means of communication.

This paper shows that there are other design opportunities, besides experimenting with boarding strategies, for airports and airlines to reduce boarding times. Unlike most boarding methods, these solutions do not require additional actions or touch-points, while these concepts have the potential to improve passenger experience by providing a faster and more comfortable boarding process.

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design course. Special thanks also to Caroline Kroon and Marijke Dekker, design coach and ergonomics expert, as well as the design students from Delft University of Technology.

Glossary: The abbreviations used in this study to indicate flights are 3-letter IATA codes of the following airports: Amsterdam Airport Schiphol (AMS), Barcelona Airport (BCN), Pisa (PSA), Sao Paulo (SAO), Moscow Sheremetyevo (SVO).

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Conflicts of interest: none

List of figures