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Access-To-Egress III: Repeated Measurement of Factors That Control the Emergency Evacuation of Passengers Through the Transport Airplane Type-III Overwing Exit

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16. Abstract

Simulated emergency evacuations were conducted from a narrow-body transport airplane simulator through a Type-III overwing exit. The independent variables were passageway configuration, hatch disposal location, subject group size (density), and subject motivation level. Additional variables of interest included individual subject characteristics, i.e., gender, age, waist size, and height, shown in previous studies to significantly affect emergency egress. Subjects were restricted to those who had no previous emergency evacuation (research) history.

Evacuation trials were conducted with 48 groups of either 30, 50, or 70 subjects per group, totaling 2,544 subject participants. Each subject group completed 4 evacuation trials, totaling 192 group evacuations, which included 10,176 individual subject exit crossings. The dependent variable of interest was individual subject egress time.

Small but significant independent variable main effects on mean individual egress times were found for passageway configuration ($p<.001$), subject group motivation ($p<.001$), and subject group density ($p<.05$); significance of these effects was potentiated by the extremely large number of subject observations. The effects of subject waist size ($p<.0001$), gender ($p<.0001$), and age ($p<.0001$) on mean individual egress times were much more robust. The within-subjects main effect of evacuation trial (experience) failed to achieve significance ($p<.63$), although within-subjects effects were found for group motivation level ($p<.0004$), the combination of group motivation level and hatch disposal location ($p=.03$), and the combination of passageway configuration and hatch disposal location ($p<.007$), via their interactions with individual egress trial.

The findings replicate prior research showing that the physical attributes of subjects produce large differences in emergency evacuation performance, whereas airplane configuration has minimal effects on emergency egress, as long as ergonomic minimums are respected. Where such problems do exist, evacuation experience acts to mitigate such negative effects, as does proper passenger management by flight attendants.

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Repeated Measurement of Factors That Control the Emergency Evacuation of Passengers Through the Transport Airplane Type-III Overwing Exit

INTRODUCTION

Over the last 15 years, a research program of international scope has been dedicated to examining emergency evacuations through the transport airplane Type-III overwing emergency exit. The genesis of this activity was the 1985 crash of the British Airtours Boeing 737 airplane at Manchester, England, in which a number of passengers died in an apparent attempt to approach and egress through the Type-III overwing exit (AAIB Report 8/88). A second accident involved a B-737 and a Fairchild Metroliner at Los Angeles International airport in 1991 (NTSB/AAR-91/08), in which more deaths were associated with attempts to use the Type-III exit. Restrictive cabin interior configurations limiting access to, and increasing evacuation times through, the Type-III exits were judged to be a likely cause of the deaths. Since that time, many studies of evacuation through the Type-III exit have been conducted to examine the role of airplane configuration and operation at the Type-III exit; this current study is the latest and most exhaustive attempt to identify cabin configurations and operations that promote efficient egress. This report is the third in a series of reports of this study designed to catalog the relevant factors that control evacuation through the Type-III exit. The initial report, Access-to-Egress I: Interactive effects of factors that control emergency evacuation through the transport airplane Type-III overwing exit, (McLean, Corbett, Larcher, McDown, Palmerton, Porter, Shaffstall, & Odom, 2002), provides the findings of the study with regard to the first evacuation trial for each subject group in which subjects were completely naïve regarding emergency evacuation. The second report in the series, Access-to-Egress II: Subject management and injuries in a study of emergency evacuation through the Type-III exit, (Corbett, McLean, & Whinnery, 2003), examined subject processing and health effects of airplane evacuations on subjects. This current report provides the residual evacuation-related results of the study, i.e., the effects on evacuation efficiency of additional evacuation trials for each group, as subjects became progressively more experienced in emergency egress.

METHODS

Research Design. The study employed a 4-way (Passageway Configuration x Hatch Disposal Location x Subject Group Motivation Level x Subject Group Density) factorial design. Motivation level was nested within subject group density, which was distributed uniformly across passageway configuration nested within hatch disposal location (see Table 1). Subjects were screened out for prior experience in evacuation research; after the fact it was discovered that one of the subjects had been in an actual emergency airplane evacuation.

In addition to passageway configuration, the other independent variables in the design were selected for their known effects on egress performance, as well as their potential for interactions with passageway configuration, that could address the issue of access to egress. Hatch disposal location was chosen because of the potential for a mislaid hatch to negatively influence access to the exit; subject motivation level was included because of the demonstrated ability of financial incentives to produce extreme subject behaviors (e.g., Muir, Bottomley, & Hall, 1992) that can impede egress; and subject group density (size) was included because a prior research study had shown nonlinear increases in evacuation time, as the number of subjects per group was increased (McLean, Corbett, & George, 1999).

Participants. A total of 2,400 subjects was apportioned among the 48 experimental groups, one-third of which contained either 30, 50, or 70 subjects. An additional 144 subjects were added to the subject pool as *hatch operators* (one for each evacuation trial), resulting in a total of 2,544 human subjects being employed. The subject pool was comprised of 51% males and 49% females; subjects ranged in age from 18 to 65 years of age, in weight from 95 to 416 pounds, and in height from 54 to 81 inches.

Motivation. The low motivation condition, often termed *cooperative egress*, was established by a briefing given prior to each trial. Subjects in all groups were told that the airplane had *crashed* and was *on fire*, and that to stay alive they had to hurry to get out. This was the only instruction for half the groups. In the high motivation

Table 1

Research Design with Mean Total Group Evacuation Times*

Hatch Location:		Inside				Outside			
Passageway:		6"	10"	13"	20"	6"	10"	13"	20"
Density	*Motive*								
Low (30)	Low	48.05	49.53	48.45	49.15	55.17	66.21	51.58	45.89
	High	51.33	66.13	53.33	44.30	56.07	48.94	51.45	51.41
Medium (50)	Low	85.67	91.80	87.14	88.45	84.87	89.57	84.00	71.89
	High	84.45	82.86	94.02	78.84	83.04	93.75	84.00	71.89
High (70)	Low	116.69	120.37	127.75	106.03	106.12	134.99	122.08	100.96
	High	124.61	120.15	134.18	114.43	119.87	121.56	109.32	108.99

* Each cell contains the average group evacuation time in seconds for that condition.

condition, *competitive egress*, double pay was offered to subjects who were among the first 25% of their group to evacuate the airplane simulator, averaged across all 4 evacuation trials. The technique of averaging across trials was intended to assure sustained competition among all subjects in any individual trial; seat assignment was rotated on evacuation trials to give all subjects equal opportunity to earn the bonus.

Apparatus. The airplane simulator was configured with six-abreast seating (e.g., B-737) and equipped with a single Type-III overwing exit located on the right side of the cabin 40% of the total distance aft of the front door. The exit opening was 20" wide and 38" high, with a step-up distance of 18" inside the simulator and a step-down of 27" from the centerline of the exit to a sloped *winglet* outside the simulator. The weight of the hatch was set at 45 pounds for all trials.

Passageway Configuration. Four different passageway configurations leading from the main aisle to the exit were used in the study; three of these included single passageways between triple seat assemblies and the fourth employed 2 passageways, one fore and one aft of a seat assembly in which the outboard seat had been removed. The single passageways employed 10", 13", and 20" passageway widths, with 14", 10", and 5" aft seat encroachment distances, respectively; the dual passageway configuration with the outboard seat removed had the seat assembly placed directly adjacent to the Type-III exit. Figures 1 through 4 depict the passageway configurations employed. The tray tables in the passageway seats were stowed in the rigid armrests; all seat backs throughout the cabin were locked to prevent breakover. Remaining seat pitch was set at 31 inches.

Hatch Disposal Location. At the start of each evacuation trial, the Type-III exit hatch was removed from its typical location in the side of the fuselage by the hatch operator, who placed it either inside or outside the simulator, depending on the specific experimental condition. The hatch was placed on the exit row seat assembly for *inside* hatch disposal (e.g., Figure 5); *outside* hatch disposal was achieved by having the hatch operator throw it through the exit opening onto the winglet (e.g., Figure 6), where a research confederate would pull it out of the way to minimize the possibility of subject injury during the ensuing evacuation. In both cases the hatch operator would then climb through the exit, either leading the evacuation or not, depending on whether another subject had squeezed through first.

Hatch Operators. Hatch operators were selected randomly as they entered the lab and were sequestered, away from their evacuation group, where they were briefed about hatch operation by being shown graphics taken from a typical airline safety briefing card (see Figure 7). No verbal instruction was given to them about the procedure or the evacuation trial for which they would be opening the exit, except to inform them that a buzzer would be used to start the evacuation. Immediately before the evacuation trial in which each hatch operator participated, s/he was escorted to the simulator and seated immediately adjacent to the Type-III exit. After each of the first three trials for

Figure 1
20" Passageway With 5" Encroachment

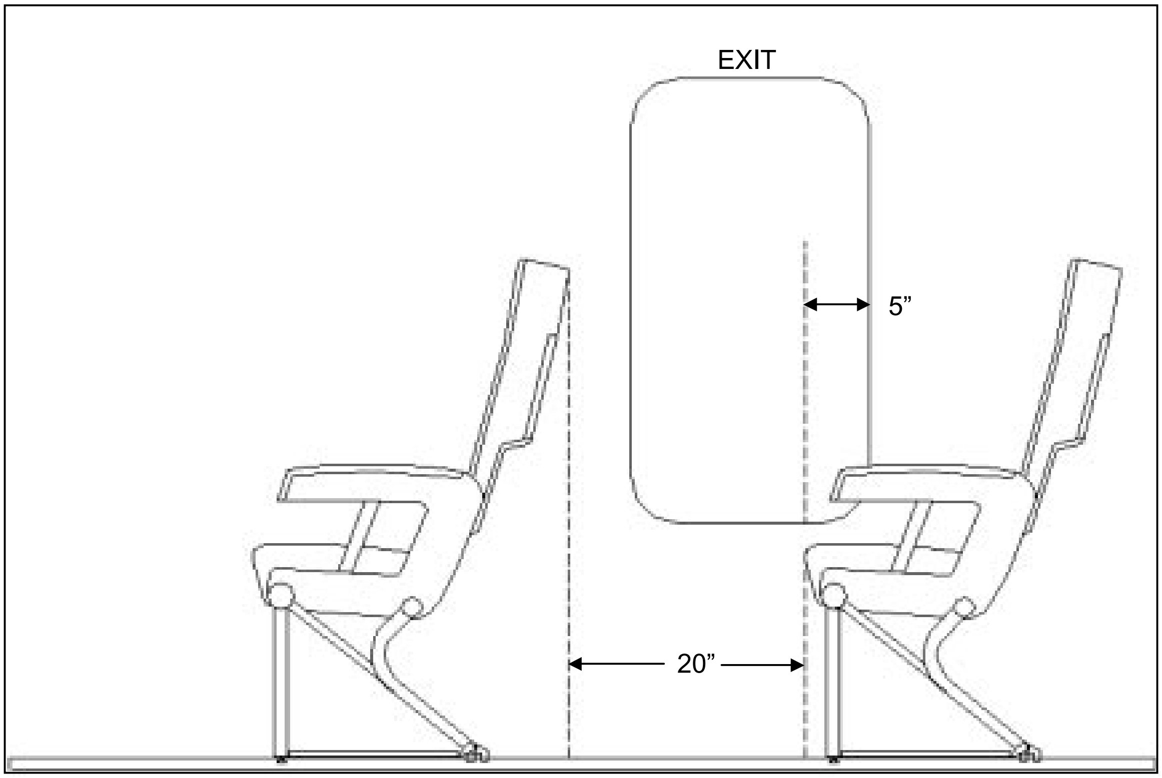


Figure 2
13" Passageway With 10" Encroachment

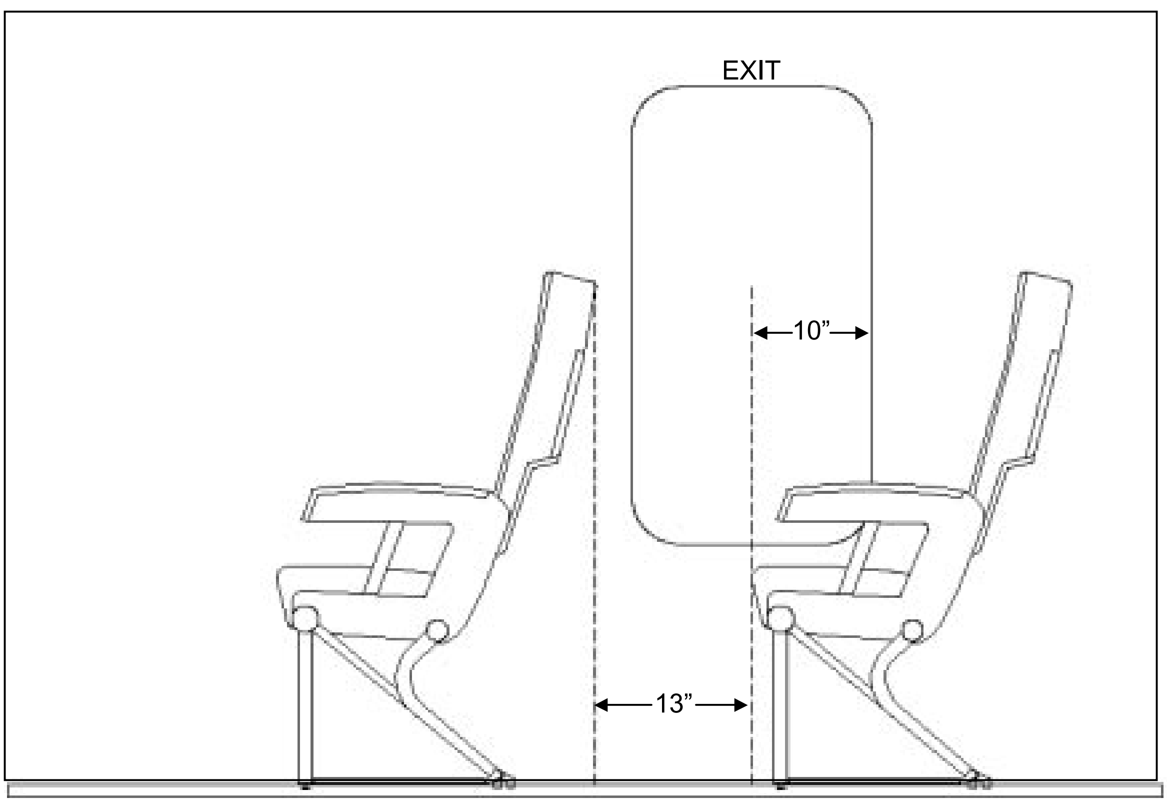


Figure 3
10” Passageway With 14” Encroachment

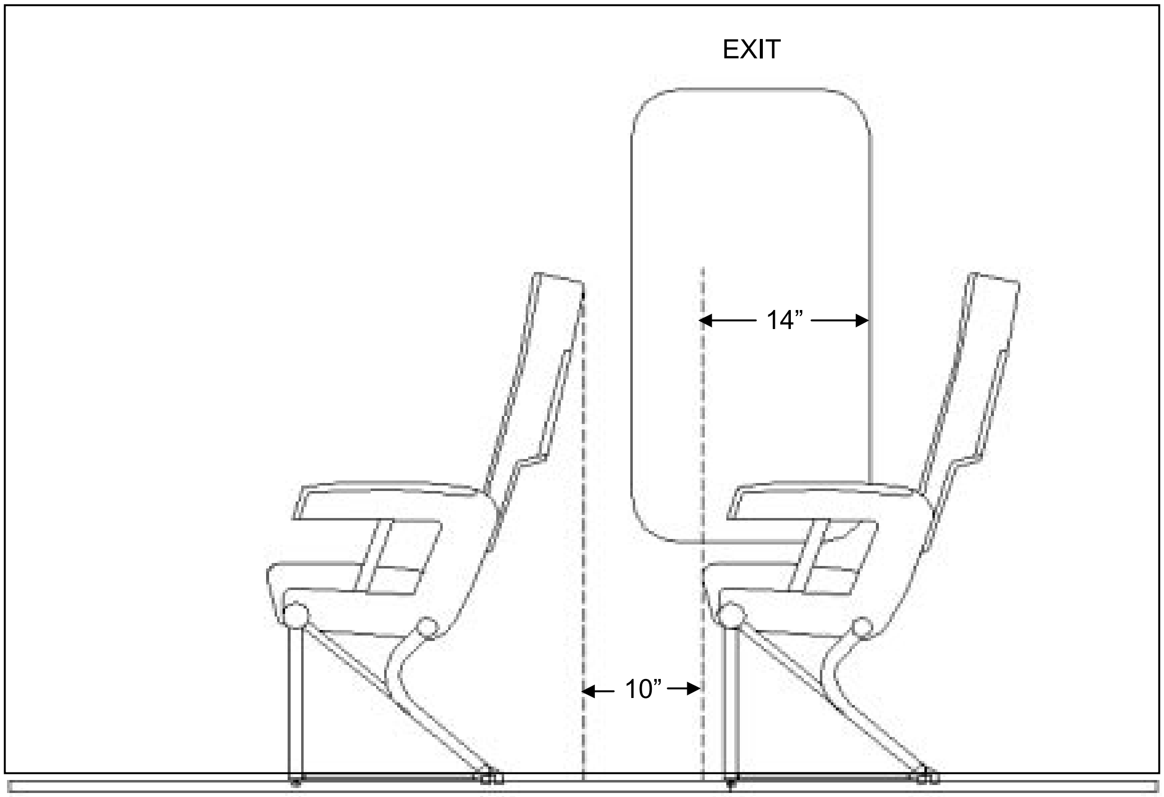


Figure 4
Dual 6” Passageways With Outboard Seat Removed

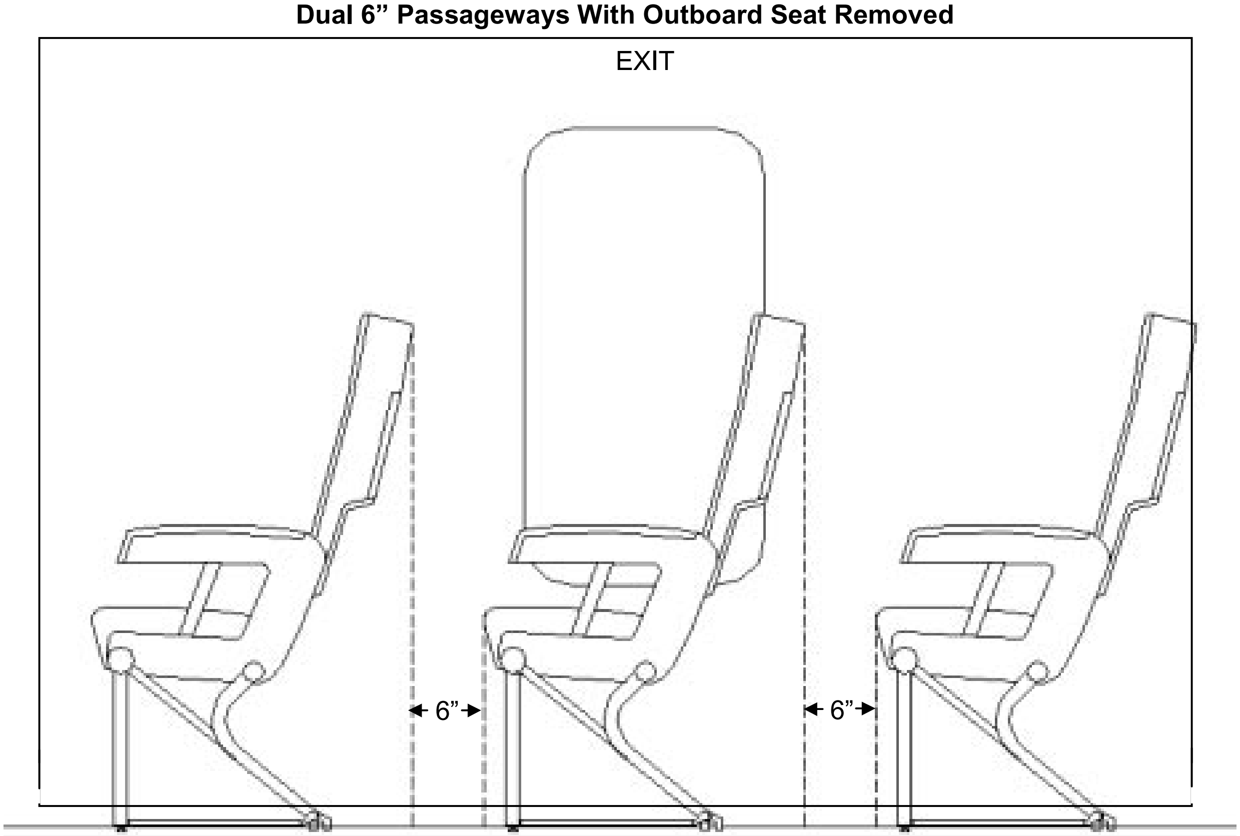
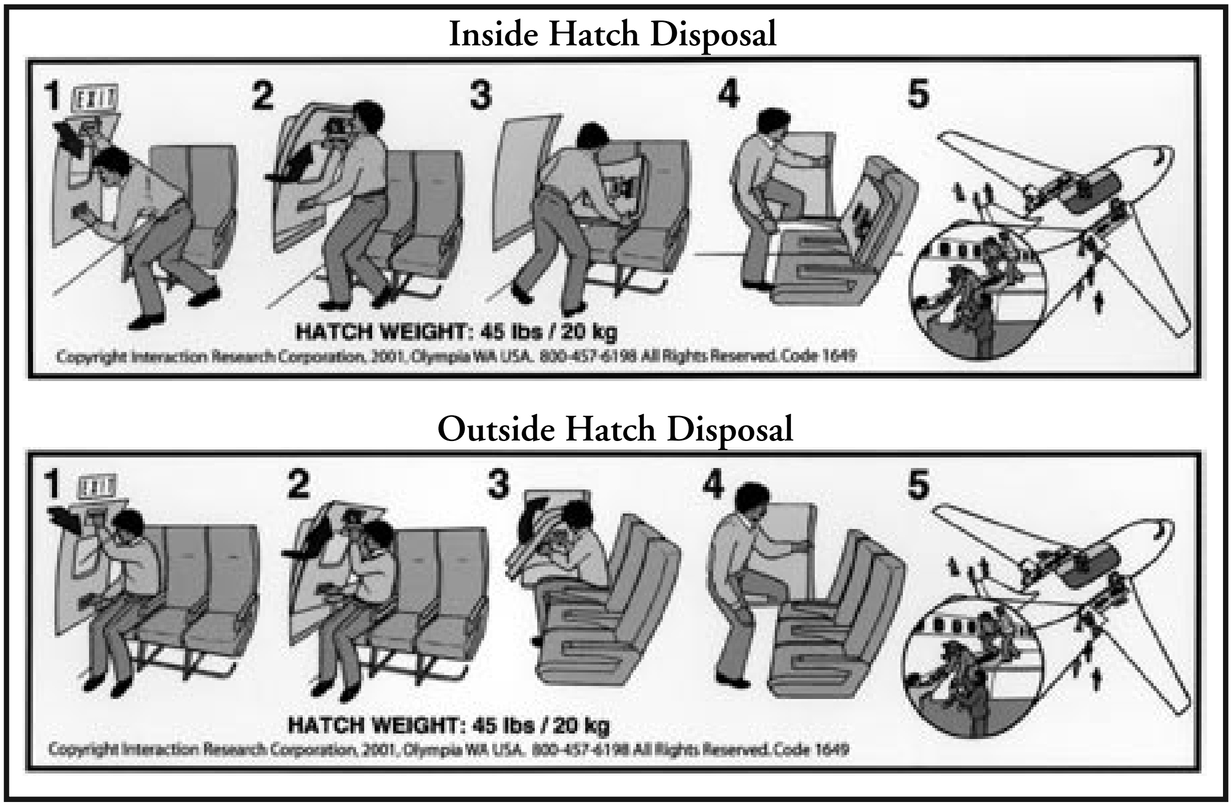


Figure 5
Typical Inside Hatch disposal Location

Figure 6
Typical Outside Hatch disposal LocationFigure 5

Figure 7
Hatch Operator Briefing Cards



each group, the hatch operator was relocated to another area to preclude the possibility of information sharing with subsequent hatch operators.

Flight Attendant Participation. Two flight attendants, one located in the front of the cabin and one in the rear, were seated in jumpseats at the start of each trial. At the sound of the start buzzer, the forward flight attendant pointed at the exit and commanded the hatch operator to "Open That Hatch." Both flight attendants immediately started commanding "Unbuckle Your Seatbelts… Evacuate… Get Out… Get Out… Hurry," as they started herding the subjects toward the Type-III exit. The flight attendants continued to command the evacuation throughout each entire trial, but they were not allowed to physically assist subjects in any way. Their purpose was to keep subjects *on task* as would be expected in an actual emergency evacuation.

Procedure. Prospective subjects were in-processed according to IRB requirements, and then they completed questionnaires about their personal demographics and their attention to, and knowledge about, actual preflight briefings on airliners. Their physical attributes (height, weight, etc.) were then measured, and they were photographed for identification purposes before being escorted to the simulator. After a familiarization briefing, they were given a boarding card with the first seat assignment. They entered the simulator and seated themselves accordingly. Following any subject questions, the *preflight* briefing was read, the flight attendants assumed their assigned places, and the start buzzer was sounded after a variable interval of 5 to 30 seconds. The flight attendants began shouting and gesturing for subjects to unbuckle their seatbelts and proceed through the exit. The hatch operator, seated next to the exit, removed the hatch and disposed of it, allowing the evacuation flow to begin. After the trial was over, subjects were regrouped outside the simulator for the next trial.

Data Archival, Reduction, and Analysis. Eight video cameras, 4 inside the simulator and 4 outside, recorded all experimental trials (see Figure 8). Videotapes of each trial were examined manually to obtain group and individual evacuation times; the data were analyzed using the multiple regression, analysis-of-variance, and analysis-of-covariance routines in *SPSS*® 10.0 (1999).

Each subject group completed four evacuation trials. Total group evacuation time for each trial was defined as beginning at the time the start buzzer sounded and lasting until the last subject had traversed the Type-III exit opening (see cells in Table 1). Because of the differences in the number of subjects within the groups, no statistical analyses were conducted on these group times. Instead, the times were divided into hatch removal/disposal and individual subject egress times. Hatch removal and disposal time lasted from the initial sounding of the start

Figure 8
Data Acquisition and Archival System

buzzer until the first evacuee began to emerge from the exit opening. Individual subject egress time was defined as the period lasting from the time (videotape frame) one subject had completely passed through the exit opening until the time the next subject was completely through the opening.

The results related to operation of the hatch and preparation of the exit for evacuation were reported in McLean et al. (2002), as were the first trial (between-subjects) effects on individual egress time of the independent variables and the individual subject attributes. The mean and repeated-measures independent and human subject variable effects on individual subject egress times across all 4 evacuation trials are reported here.

RESULTS

The large number of individual egress time observations provided an enormous amount of statistical power, allowing the data to be screened for significant egress time outliers, i.e., those times greater than 3 standard deviations above the mean for each passageway configuration. This resulted in the removal of 131 of the 10,176 individual subject egress times; outlying times ranged from 3.77 to 18.63 seconds. These times resulted from errant individual subject behavior, the exit being jammed with subjects, or the hatch becoming an impediment. However, no evacuation trial was halted because of exit blockade.

Note that, in the figures presented below, solid lines are used to connect interval data points within any category, whereas dotted lines are used to connect data points for discrete classes of a variable. For example, the 10", 13", and 20" passageway data points are connected via solid lines, and then the dual 6" passageway data points are connected to the single 10" passageway data points via a dotted line. This particular distinction was made to highlight the fact that it was the additional passageway available for egress with the most restrictive (6") passageway configuration that afforded individual egress times generally comparable to those produced by the less restrictive of the single passageway configurations.

All variables, including both design factors and subject attributes, were subjected to an initial multiple regression analysis to assess relative significance with regard to mean individual subject egress time. In a manner identical to the effects on egress found for subjects in their first evacuation trial, waist size accounted for the largest amount of variance in the data ($p<.0001$), followed by gender (p<.0001) and age (p<.0001). Neither subject height, nor any of the independent variables added further to the regression model.

These same variables had been found in the study of the first (naïve subject) trial to account for the largest amount of variance in the data; thus, the cumulative effects of individual subject egress experience did not alter the relative importance of personal characteristics in controlling egress performance. This equivalence of effects provided the rationale for an identical set of analyses on the data from all evacuation trials. First, individual subject characteristics were categorized to provide interval data that would allow better visualization of the subject attribute effects. Five subcategories of age, waist size, and height, distributed to achieve a similar number of subjects per sub-category, were created in addition to gender. These variables were subjected to a univariate analysis of variance (ANOVA) of mean individual egress times across all trials. Significant main effects were replicated for waist size (p<.001; Figure 9) gender (p<.001; Figure 10), and age (p<.001; Figure 11). Subject height also unexpectedly achieved statistical significance (p<.02; Figure 12).

Mean Effects of the Independent Variables. A univariate analysis of variance (ANOVA) was used to assess the within-subjects effects of the independent variables on mean individual egress time across all trials. There were small but significant main effects of passageway configuration (p<.001; Figure 13), subject group motivation (p<.001; Figure 14), and subject group density (p<.05; Figure 15), but the hatch disposal location main effect failed to achieve significance (p<.11; Figure 16). Significant interaction effects were also found for passageway configuration by hatch disposal location (p<.02; Figure 17) and passageway configuration by hatch disposal location by subject group motivation level (p<.04; Figure 18). The significance of the main effects resulted primarily from the extremely large degree of statistical power. Importantly, the general character of these main effects was unchanged from the results obtained on only the first trial of the study (see McLean et al., 2002). The passageway configuration by hatch disposal location interaction effect was also much like the first-trial interaction effect, although the differences in individual egress time for the hatch disposal locations at the 6" passageway configuration on the first trial were eliminated in subsequent trials to reduce the significance of the interaction effect. The remaining significance of that 2-way interaction was shown in the passageway configuration by hatch disposal location by subject group motivation interaction effect to result from significant differences in individual egress time in the 13" passageway configuration. Figure 18 shows the increase in individual egress time in the 13" configuration when the hatch was placed inside the airplane simulator; this increase in egress time was produced by the hatch being dislodged from its resting place on the seat assembly in some of the trials to become an impediment to those evacuations. In sum, these effects generally mirrored those in the first (naïve-subjects) trial.

A (2-way) passageway configuration by subject waist size interaction effect (p=.005; Figure 19) was found, as was a 3-way interaction effect for the combination of passageway configuration, subject waist size, and gender (p=.002; Figure 20). A 3-way interaction effect was also found for the combination of passageway configuration, subject age, and subject gender (p<.0004; Figure 21). The character of all these effects was very reminiscent of the first trial effects, owing to the generally increased individual egress times for wider, older subjects, particularly women. These effects became more pronounced as the passageway configuration became more restrictive.

The relative magnitude of effects, including both the independent variable and subject attribute effects, can be seen in Figure 22, which displays the large influence that the subject attributes had on the evacuations. Except for a couple of minor position shifts within this magnitude of effects hierarchy, the relative effect of each variable on individual egress time was maintained from the first through the last trial, suggesting that the general character of the evacuations did not change as subjects became more experienced.

Repeated Measurement of the Independent Variable Effects. A repeated-measures analysis of covariance (ANCOVA), using the three regression model (human subject) factors as covariates, was used to assess the within-subjects effects of the independent variables on a trial-by-trial basis. The expected main effect of evacuation trial failed to achieve statistical significance (p<.63; Figure 23), despite a small improvement in egress time with increasing evacuation experience. However, significant differences in the effects of certain of the independent variables were shown across trials via interactions of evacuation trial with subject group motivation level (p<.0004; Figure 24), the combination of subject group motivation level and hatch disposal location (p=.03; Figure 25), and the combination of passageway configuration and hatch disposal location (p<.007; Figure 26). The (2-way) egress trial by subject group motivation level interaction effect resulted from the typical monotonic decline in individual egress time known to occur with cumulative experience in low-motivation conditions, coupled with a flatter, but generally faster, set of times in the high-motivation condition. This situation caused the respective curves to cross by the last trial, where the high-motivation subjects were slower than their low-motivation counterparts. The (3-way) evacuation trial by subject group motivation level by hatch disposal location interaction generally mirrored

Figure 9

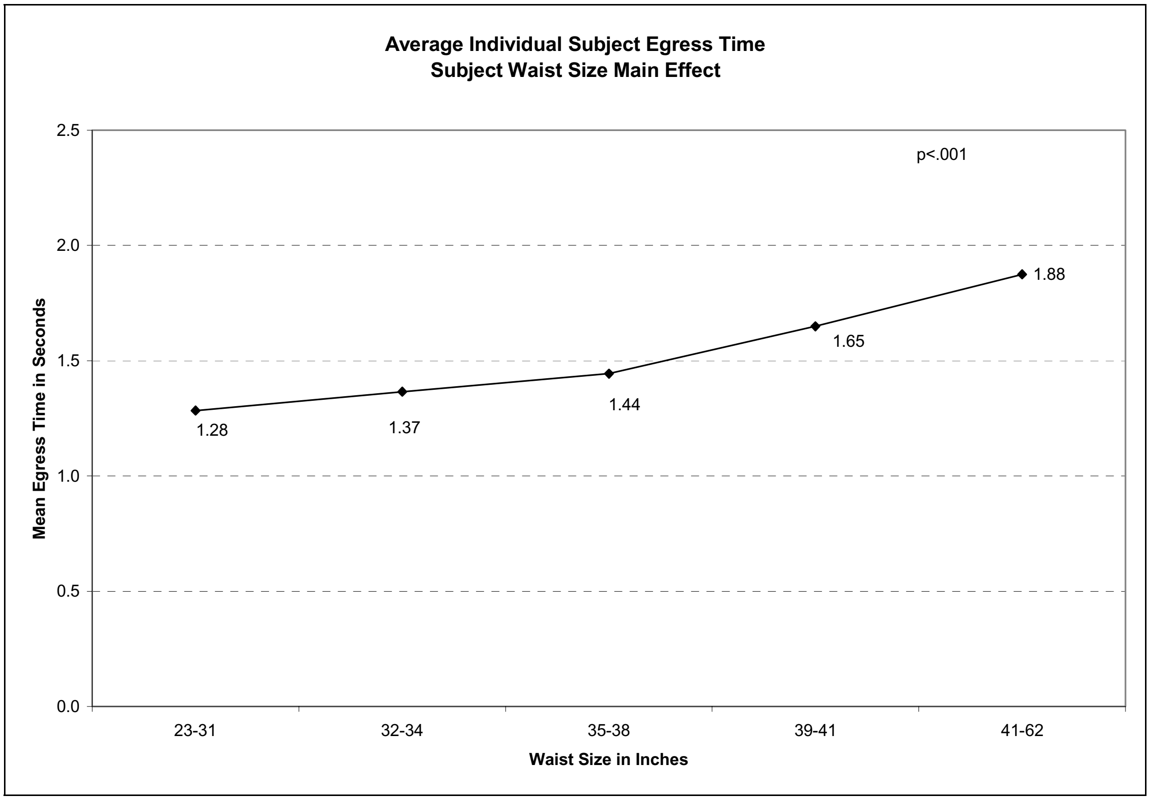


Figure 10

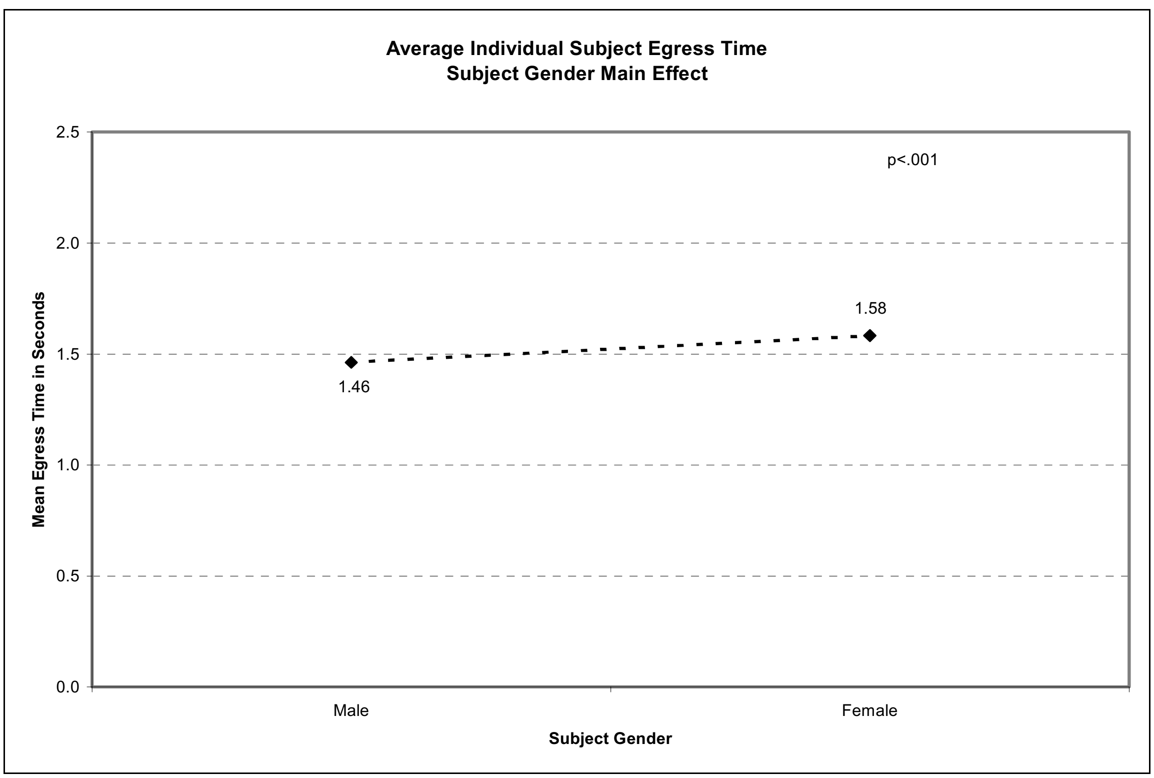


Figure 11

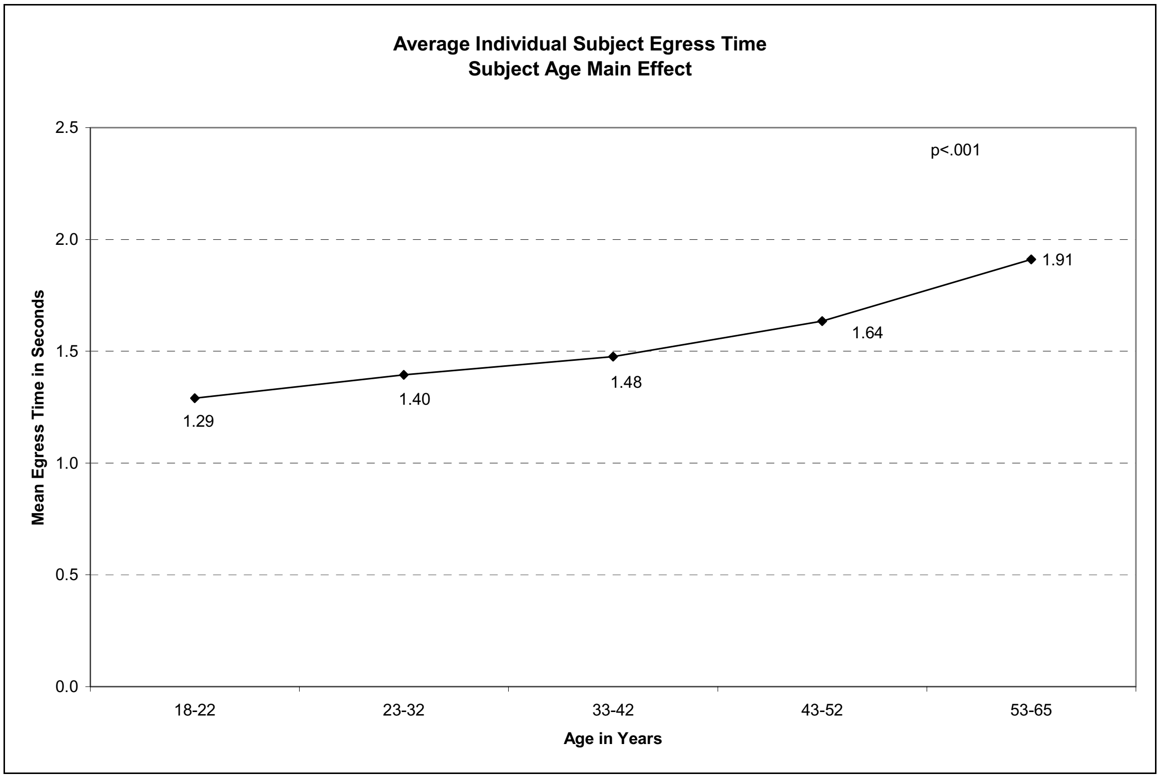
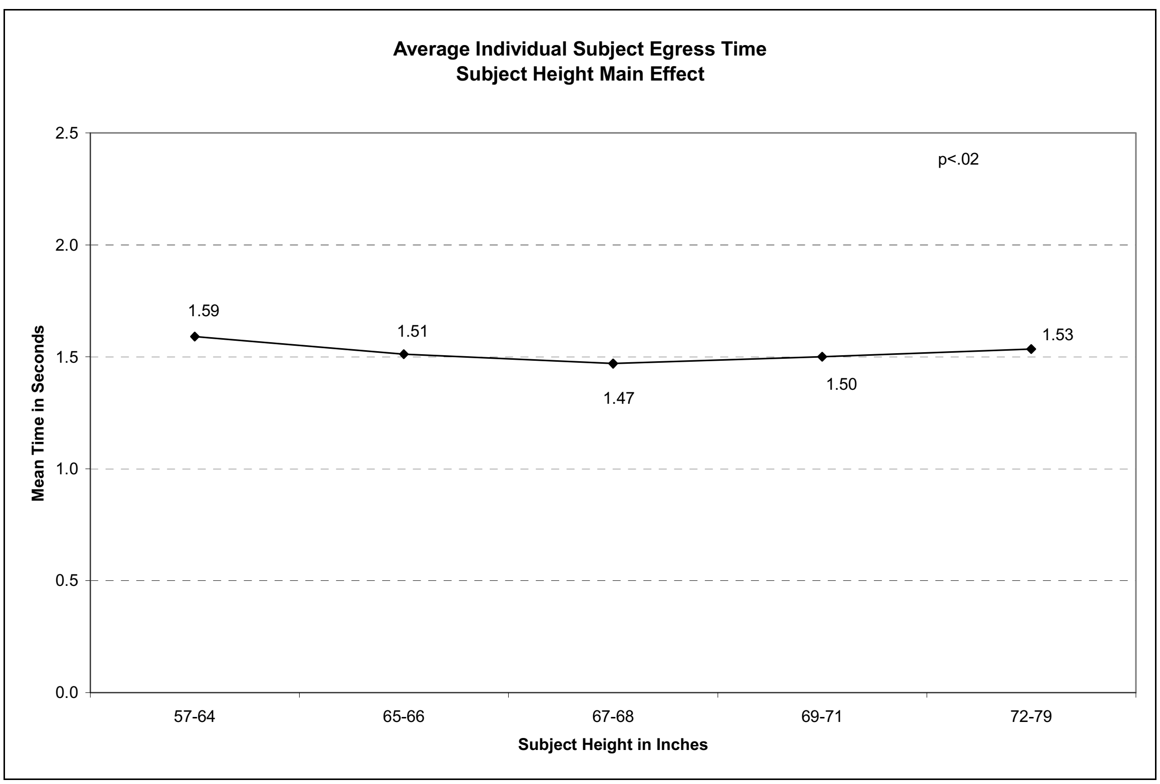


Figure 12



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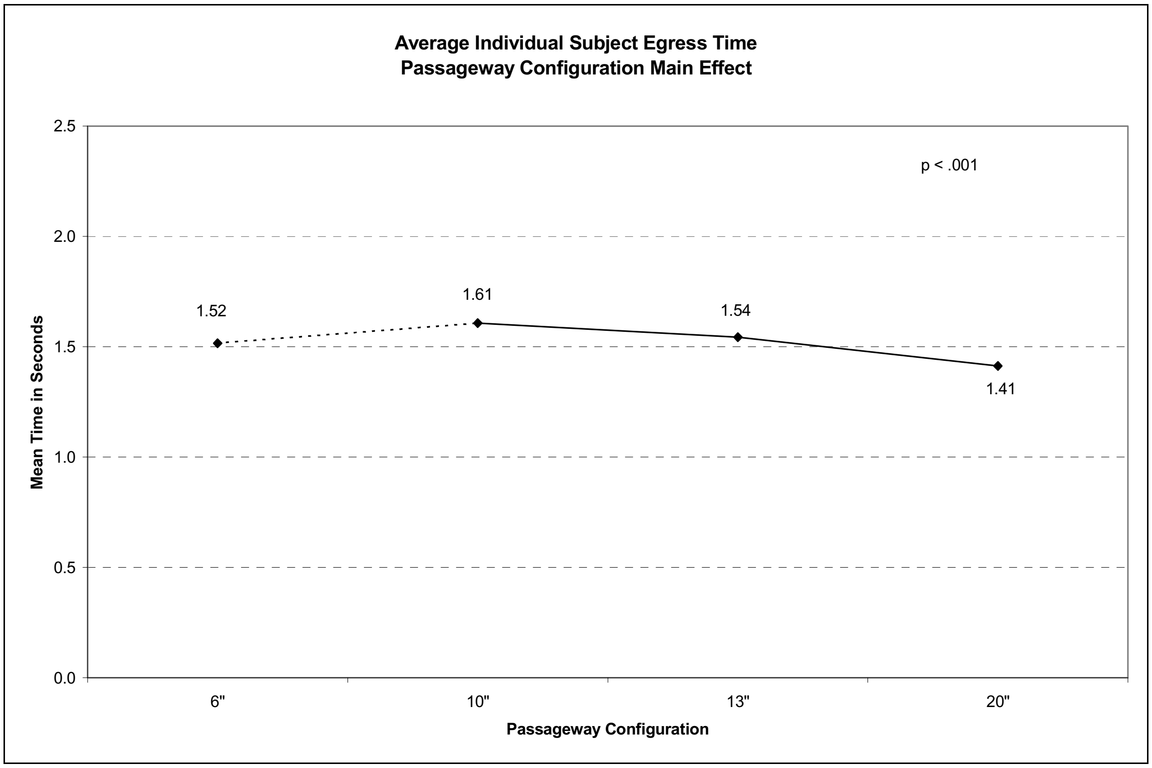


Figure 14

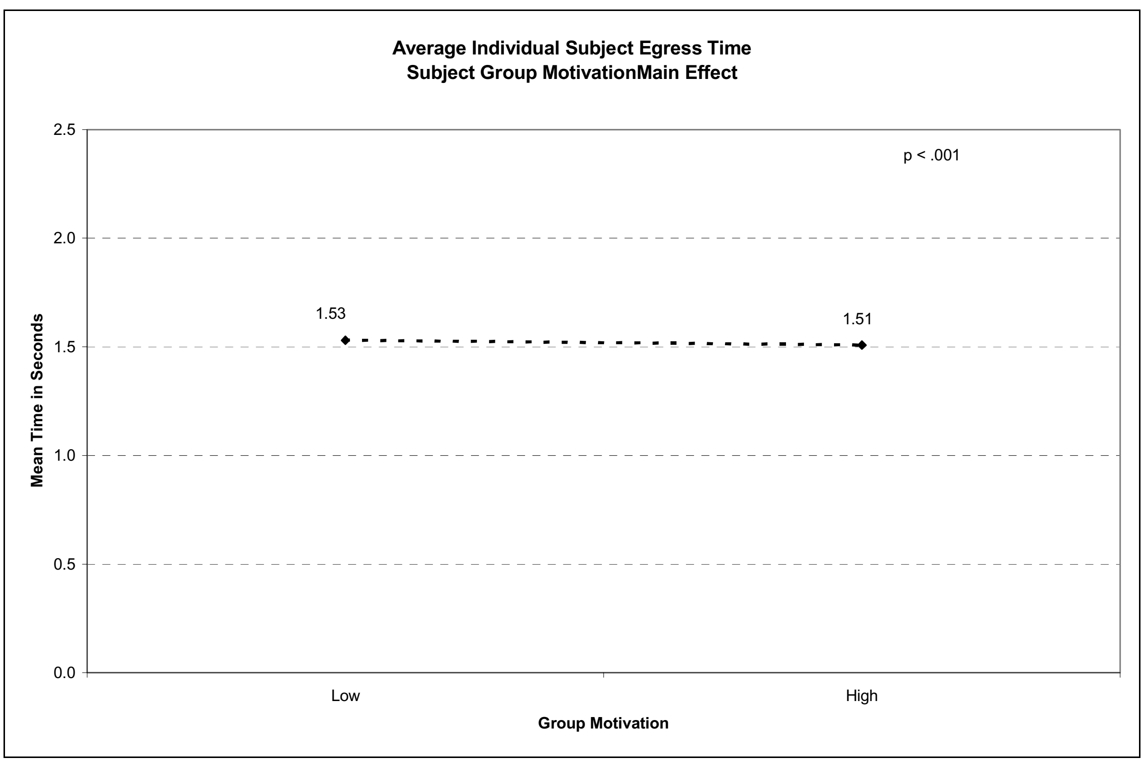


Figure 15

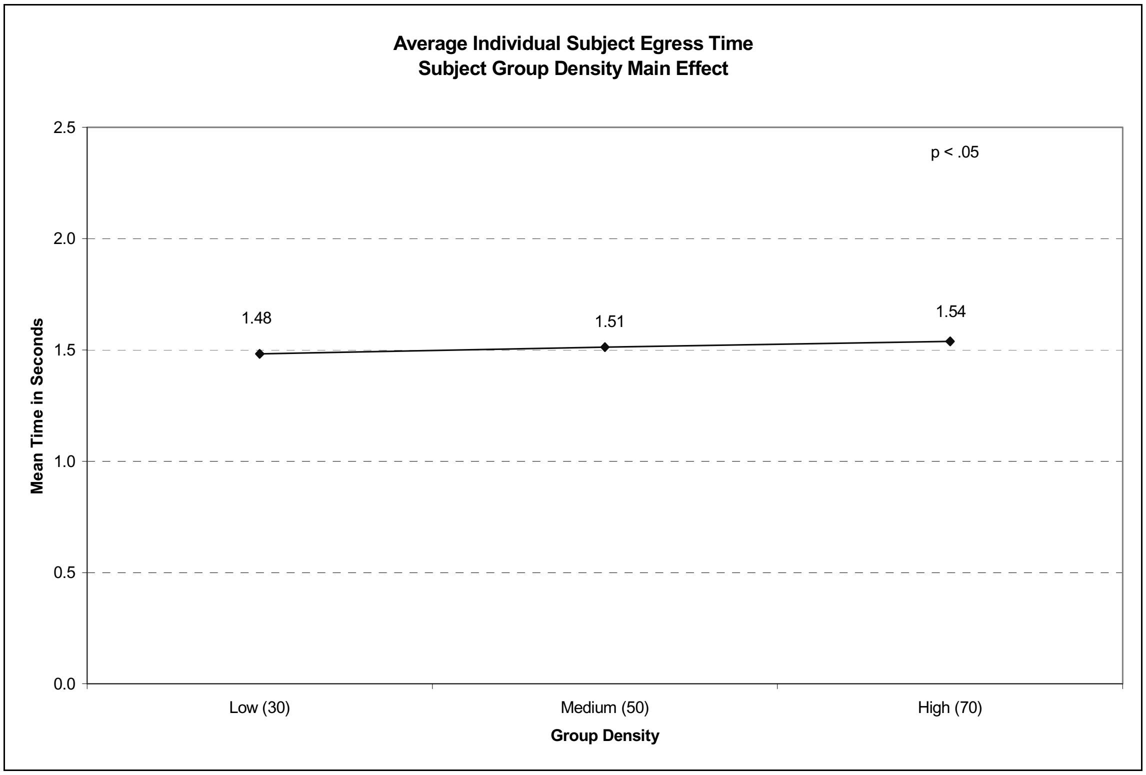


Figure 16

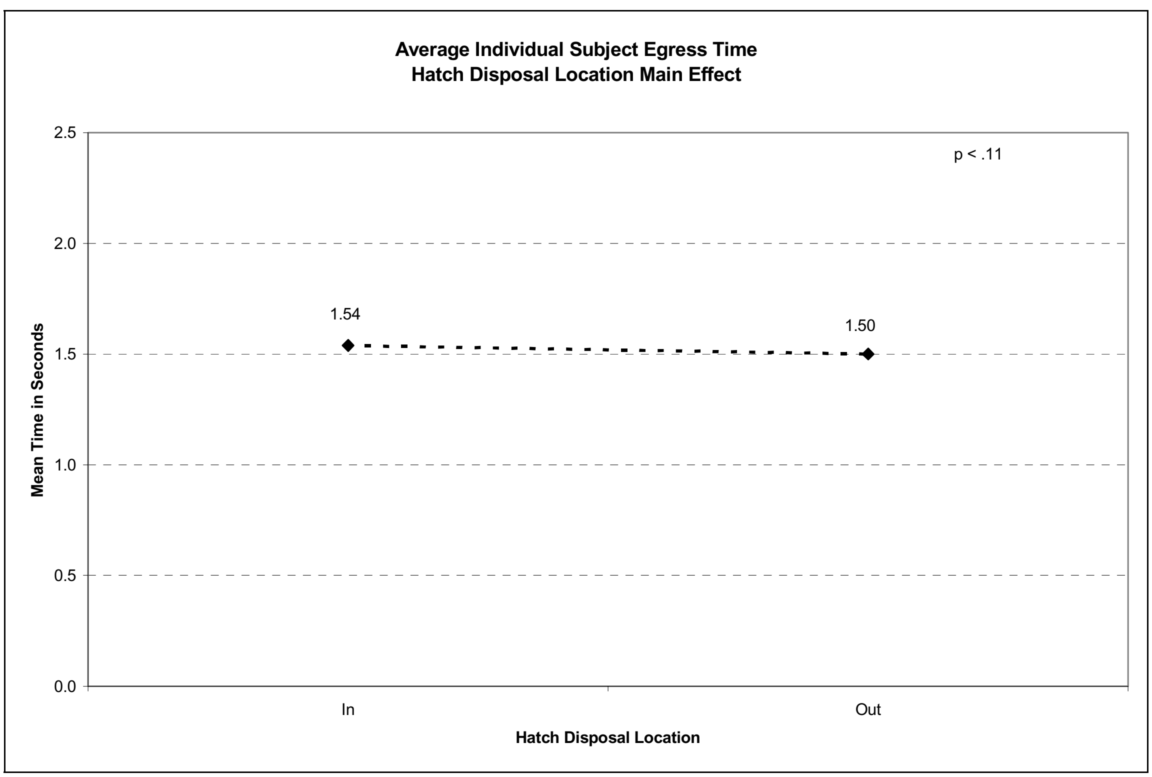


Figure 17

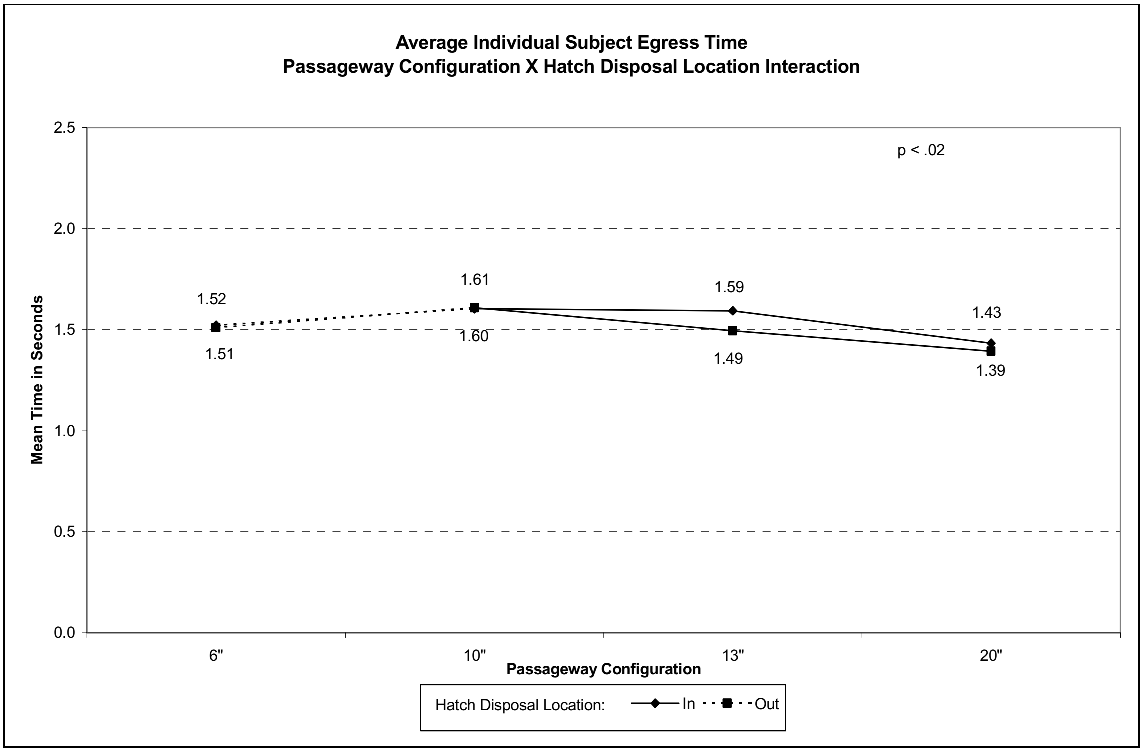


Figure 18

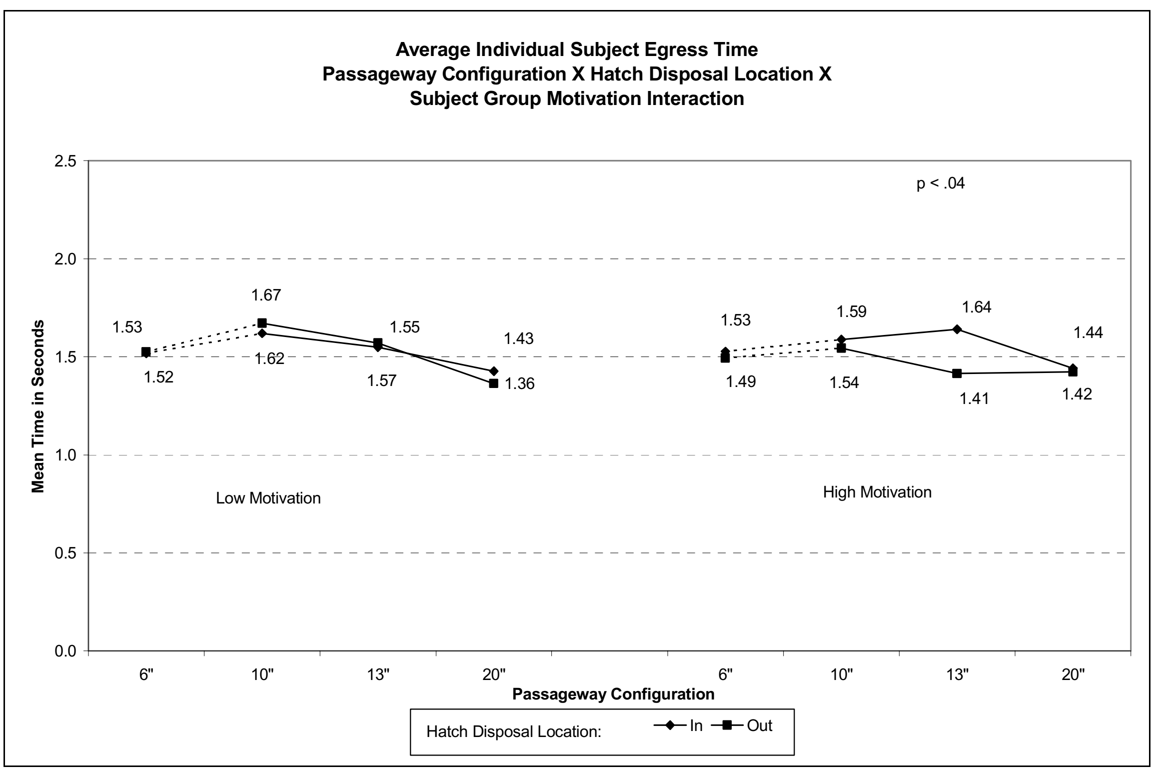


Figure 19

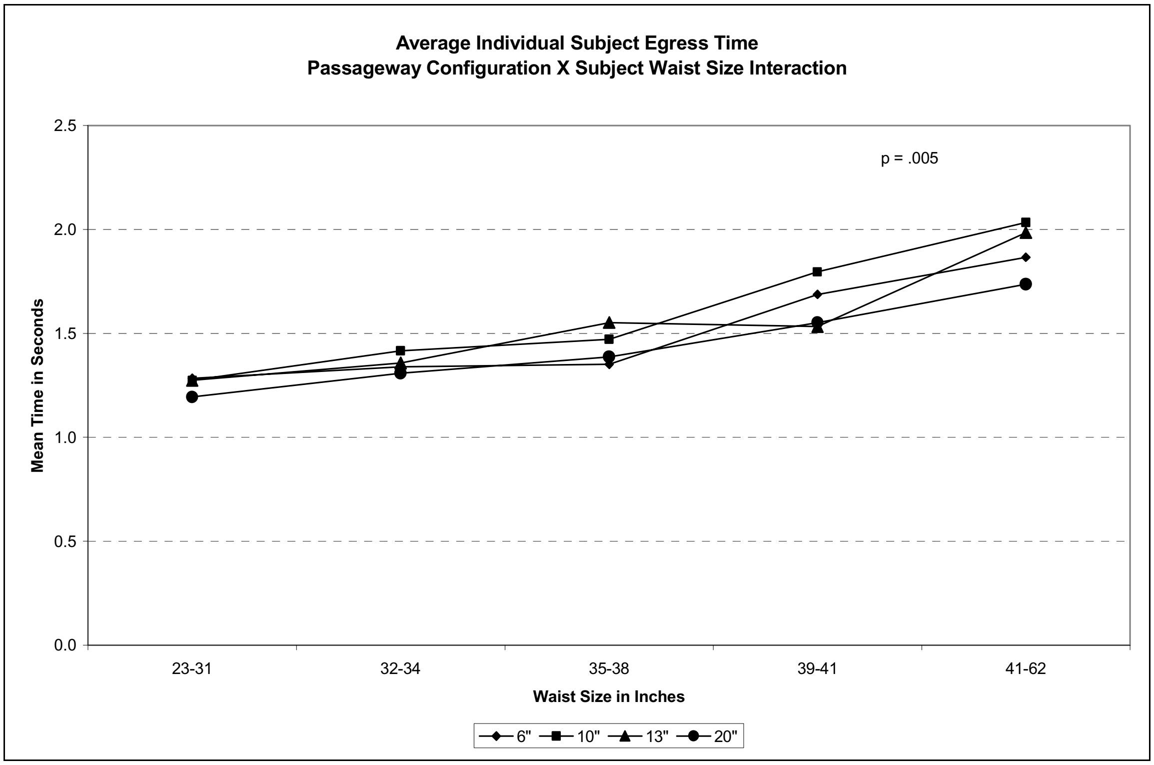
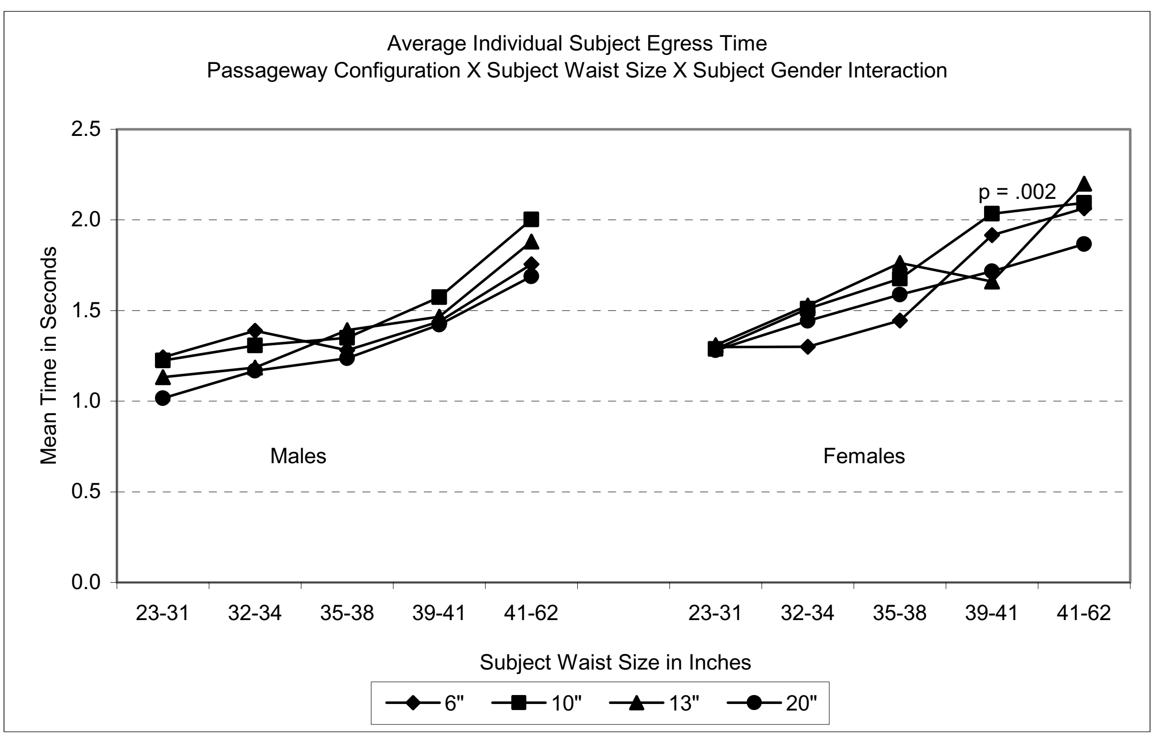


Figure 20



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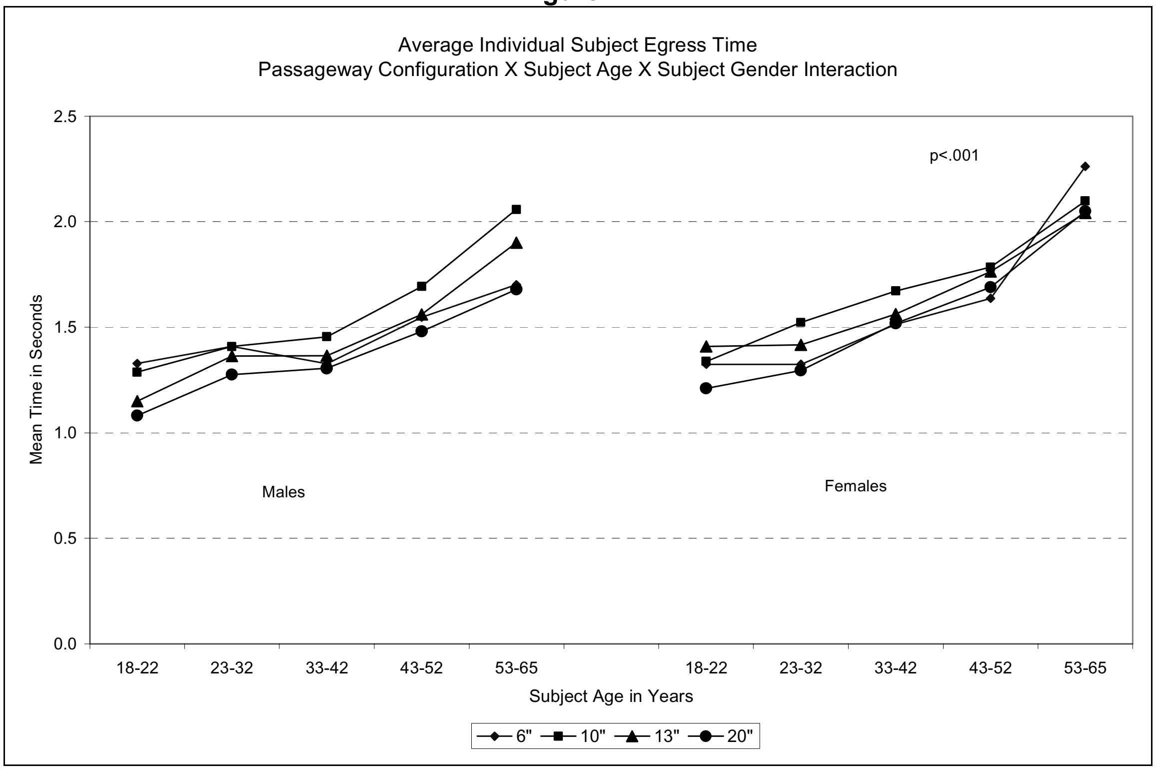
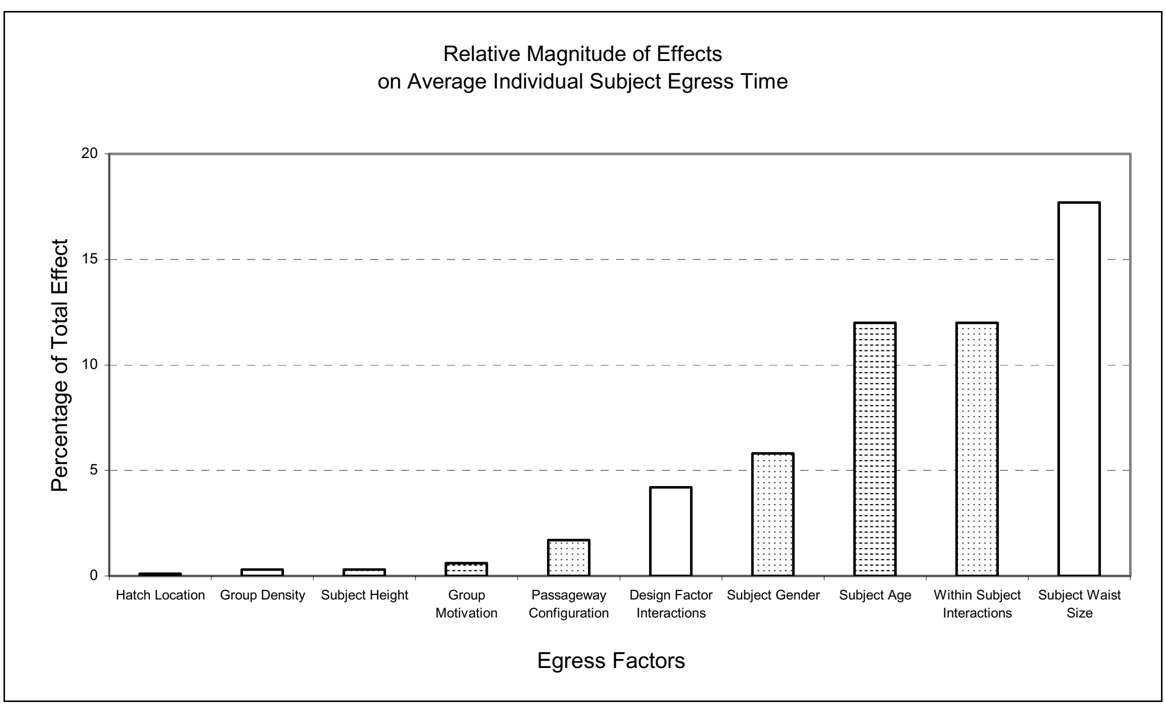


Figure 22



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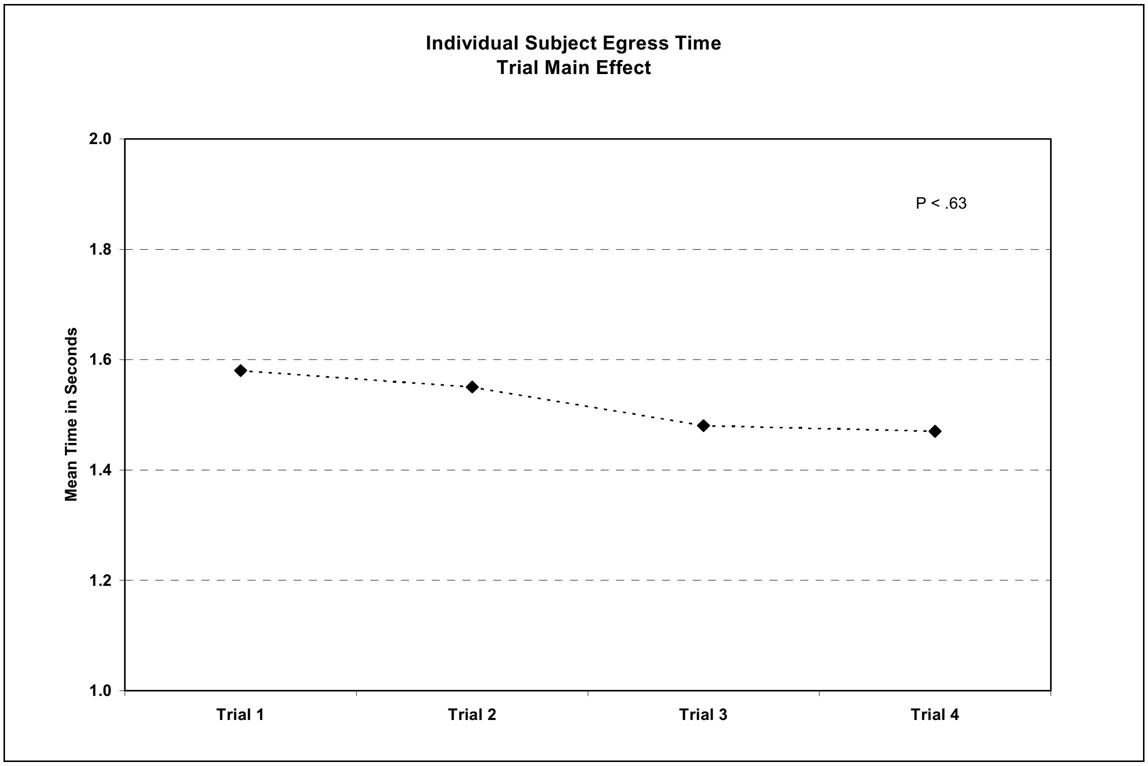

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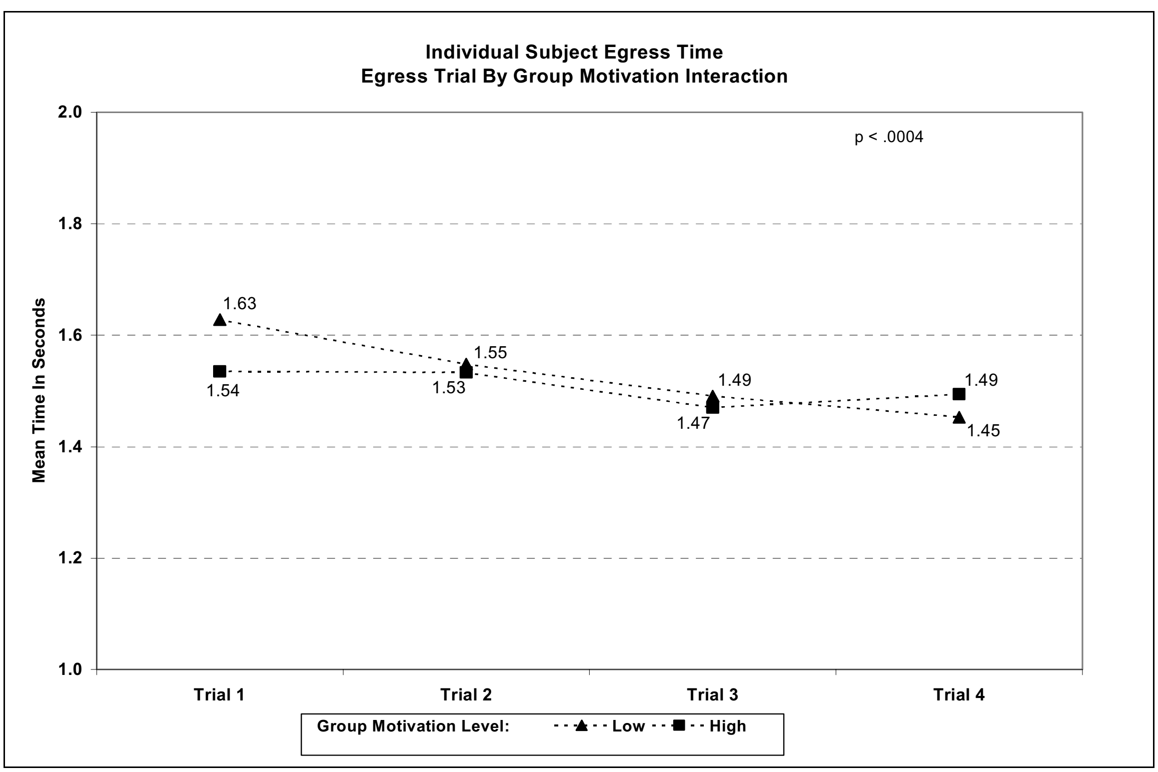


Figure 25

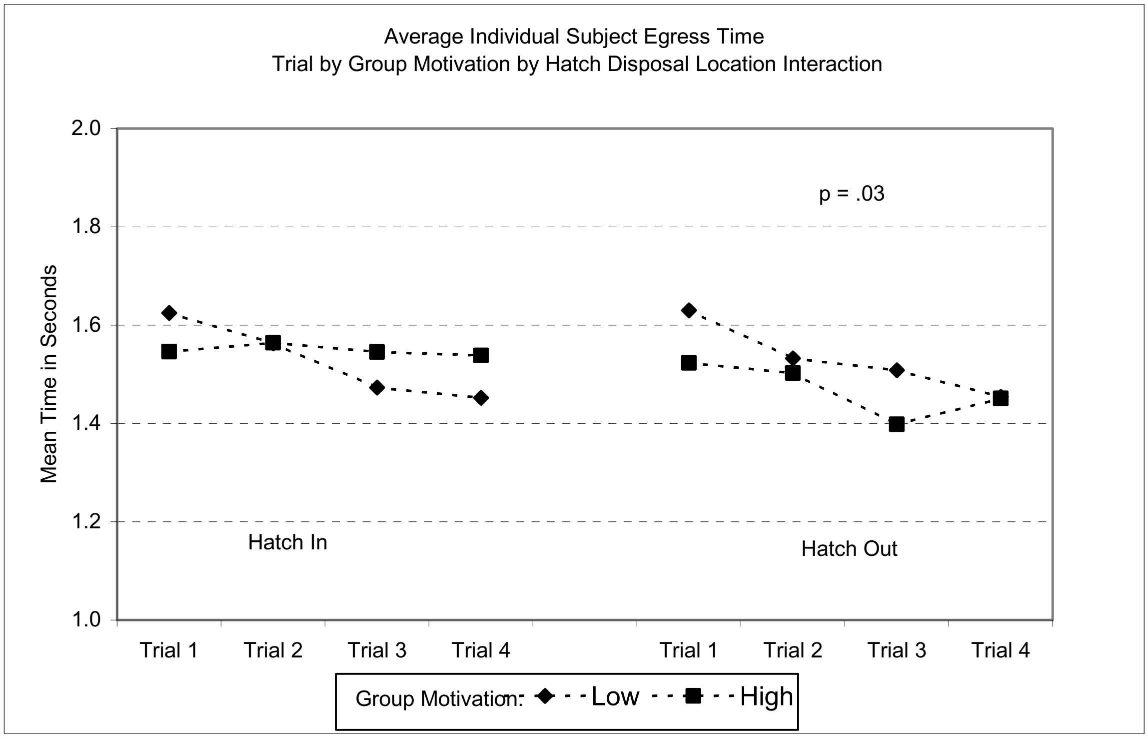
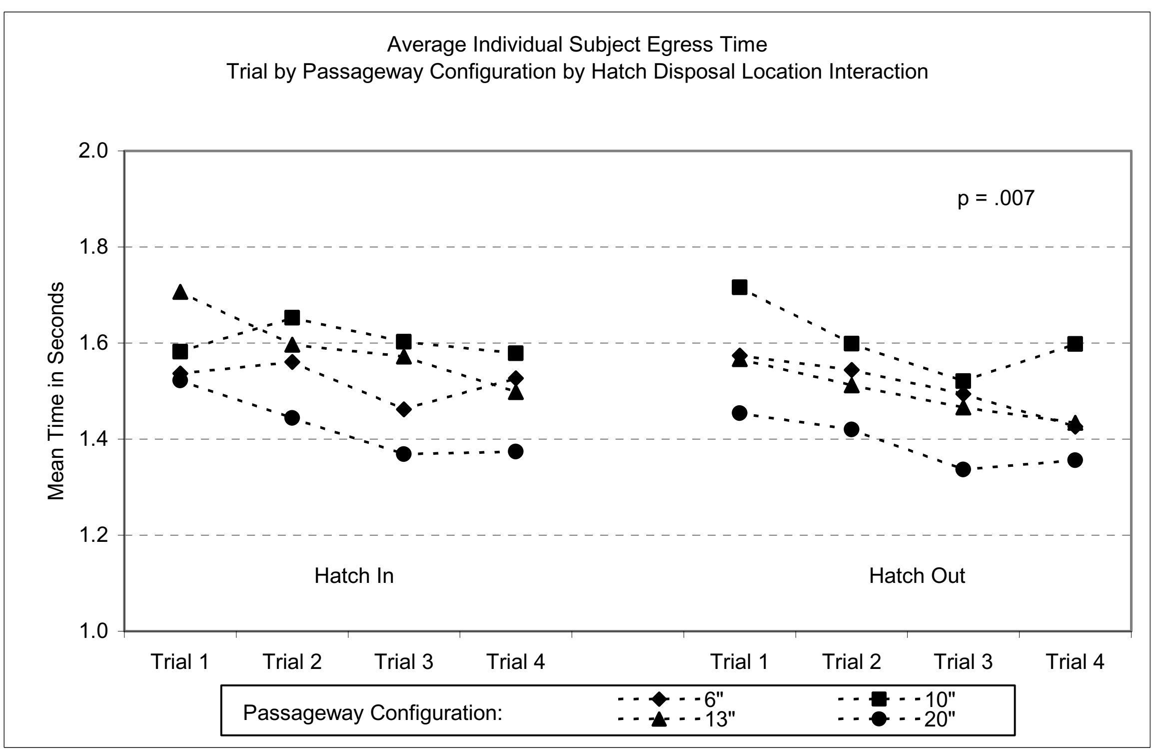


Figure 26



this formula, with the only departure being the Trial 3 high-motivation group times in the outside hatch disposal location condition. These trials appeared to be atypically faster than the other high- (and low-) motivation trials, suggesting that the 2-way interaction would likely be more robust, as a rule, than evidenced here. Again, these effects were reminiscent of those seen in the first (naïve subject) trial of this study, although the motivation effects seen there were based on between-subject differences that did not include within-subject changes in performance. The (3-way) egress trial by passageway configuration by hatch disposal location interaction effect resulted from improved individual egress times with progressive experience at all passageway configurations, although the individual egress times in the more restrictive passageway configurations were longer and more variable across the four evacuation trials. This effect, in a manner similar to that found in the first-trial analysis, was linked to the effects of errant hatch disposal locations, which produced impediments to egress. In sum, these results also mirror those found for the first (naïve subject) trial, and they generally replicate much of the effects previously reported elsewhere (cf., McLean, 2001).

DISCUSSION

The history of evacuation research involving the Type-III overwing exit has been filled with a diversity of protocols and methodologies. The relative value of these different approaches has sometimes been in question, not necessarily as a matter of *good science*, but whether or not the results could be used to model *real world* emergency evacuations, i.e., those involving naïve passengers in complex emergency situations. Such questions have often focused on the experimental designs used in the relevant studies, specifically the application of repeated-measures protocols and/or practice evacuations to reduce human performance variability when attempting to discern the effects of differences in airplane design and/or emergency procedures. The argument has been that only through the use of *typical passengers* in *unprepared evacuations* could valid results be obtained.

The design of the current study was intended to address this issue by utilizing a large number of naïve (inexperienced) subjects in a complex evacuation research protocol designed to achieve realism and high fidelity. The question of interest involved the speed of egress that subjects would be able to realize through the available escape route, i.e., the Type-III exit, and the variations in individual egress speed produced by changes in airplane configuration and operation/disposal location of the escape hatch. A motivational treatment (financial incentives) was also included for half the subject groups to induce the competition and aggressive behavior, seen in life-threatening emergencies, which had been argued as producing qualitatively distinctive egress. Finally, professional flight attendants were provided to manage the evacuations, as would be done in actual emergency evacuations. The outcome was to produce a variety of experimental conditions, each of which provided a piece to complete the puzzle of how emergency evacuations through the Type-III exit are affected by configural, procedural, and personal variables.

The results of only the first trial for each group in the study are described in McLean et al. (2002), which identified the effects of subject attributes (waist size, gender, and age) and inexperience as the primary influences on the speed of evacuations through the Type-III exit. The effects of airplane configuration and hatch operation/disposal paled by comparison. Not unexpectedly, the significant main effects of subject waist size, gender, and age found in that first (naïve-subjects) analysis were fully replicated in the results from all the evacuation trials, as reported here.

A small but significant main effect on speed of egress was also produced by differences in passageway configuration; i.e., egress speed was generally reduced as single passageways became more restrictive with respect to access to the Type-III exit. Importantly, the effects of restrictive passageway configurations were confounded with the problematic effects of inside hatch disposal, as the hatch sometimes became dislodged from its resting place on the seat to become an impediment to the evacuation. In contrast to the more restrictive single passageway configurations, the 6" dual passageway configuration produced the second fastest evacuations, on average, as the additional passageway allowed dual subject flow.

The passageway configuration by subject age by subject gender interaction effect was also a replication of the first trial effect, as older females, in particular, had egress difficulty in the more restrictive passageway configurations. A main effect of subject group motivation was also evidenced in this more expansive within-subjects analysis, even though the absolute difference in mean individual speed of egress between group motivation levels was smaller than that for naïve individual speed of egress in Trial 1. The added significance lies again in the much larger number of individual observations and the added statistical power this produces. The same can be said of the newly-found passageway configuration by subject waist size interaction effect and the passageway configuration by subject waist size by subject gender interaction effect, both of which appear to depend on the difficulties experienced by heavier subjects, particularly females, in the more restrictive passageway configurations, as was shown in the previous non-significant interaction effects in Trial 1. Thus, the average effects of the independent variables and the physical attributes of the subjects in the second analysis were little changed from the effects found in the first-trial (naïve subjects) analysis. Comparison of the relative magnitude of effects found in Figure 43 in McLean et al. (2002) with Figure 22, herein, confirms these strong similarities.

The cumulative effects of evacuation experience also conformed to expectations, as the low-motivation group subjects were able to enhance their egress performance continually throughout the evacuation trials, whereas the aggressiveness and behavioral variability found for the high-motivation subjects generally interfered with the potential for improvement. This effect occurred in spite of the effective passenger management techniques, employed by the flight attendants during the evacuations, which appeared to serve the intended purpose of keeping (high-motivation) subjects from jamming the exit opening and creating blockades. General improvements in individual egress times were the norm for most subjects in all passageway configurations, although two groups were relatively slow on Trial 4, one in the 6" passageway configuration with the hatch placed inside and one in the 10" passageway configuration with it thrown outside. These two groups appear responsible for the trial by passageway configuration by hatch disposal location interaction effect, which would generally be seen as atypical.

CONCLUSION

The use of the initial between-subjects, or this second within-subjects, analysis to answer the research questions proved not to be particularly discriminative with respect to the quality of the results, as the extensiveness of the initial between-subjects analysis (McLean et al., 2002) eliminated statistical shortcomings. Importantly, this much more extensive repeated-measures design provided a solid replication of that first-trial analysis; however, its enormous amount of statistical power could easily mislead with respect to the practical significance of the results. This would be true in cases where statistical significance was used exclusively as the rationale for application of the findings, without regard to the absolute differences in effects produced by the variable(s) of interest.

The effects on evacuation performance described above replicate fully the effects found in the first-trial-only results. In sum, the effects of the subjects' physical attributes were shown to be particularly significant with respect to speed of egress, as were the cumulative effects of high-motivation (financial incentives). In contrast, the cabin interior (passageway) configuration at the Type-III overwing exit was again shown to be of limited significance to emergency evacuation speed, although the interactions of passageway configuration with subjects' physical attributes revealed that ergonomic considerations related to restrictive passageway configurations must continue to be acknowledged in the design of airplane cabin interiors adjacent to the Type-III exit. Operation and disposal location of the Type-III exit hatch also interacted with passageway configuration, as well as with subject motivation level, to indicate that eliminating the hatch from the cabin interior adjacent to the Type-III exit is central to assuring efficient egress, especially with regard to more restrictive passageway configurations.

The ability of subjects to profit from egress experience was shown via the interaction effects of egress trial with passageway configuration, hatch disposal location, and subject motivation level, which showed reduced individual egress time as the trials progressed, as compared with the same interaction effects of the subjects on the first trial. Ostensibly, subjects became more aware of evacuation contingencies and associated behavioral requirements as their experience grew. Provision of the flight attendants also appeared to enhance evacuation performance by keeping subjects under better control (on task) during the evacuation trials. This appeared to bring a higher degree of regularity to the high-motivation results that might otherwise prove elusive in actual emergencies without the benefit of trained assistance. Both of these factors highlight the need for proper passenger management, better passenger awareness of the airplane emergency environment and appropriate evacuation/survival techniques, as well as actual experience, where possible. As passengers become more knowledgeable about the emergency environment and what to do when faced with it, less reliance on design parameters should be needed to achieve successful evacuation/survival outcomes.

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