Article

Persistence of a queue after the departure of its members

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People who take turns at a counter form a queue. Less clear is what an observer takes to be present once the other customers have gone. We varied how a room came to contain one person while holding its final appearance fixed. Each observer saw a single film. Two seconds after four people had left in service order, 85 of 120 observers reported that there was a queue, compared with 45 of 120 after four people had passed beside the counter (difference 33.3 percentage points, 95% confidence interval 20.9 to 44.3). The difference was still detectable after eight seconds. In a second experiment we allowed the remaining person to leave as well. Of 112 observers who saw the queue clear, 28 judged that a queue was present in the empty room. Twelve of 112 gave the same answer after a matched history of through traffic. Nearly all of the affirmative respondents correctly counted zero people. The result puts a limit on explanations in terms of how many bodies an observer takes to be there. It leaves open whether the remaining referent is an episode of waiting or the place at which waiting takes place.

Introduction

A person standing at a counter can be the last member of a queue or the first person to arrive before one forms. A photograph taken from the door will often fit either description. An observer who saw the room a few seconds earlier has information the photograph lacks. We asked whether that information changes the answer to a question about the present. Once the line has passed through the door, is there still a queue in the room?

Accounts of queuing have usually had an independent means of establishing that a queue exists. In Mann's overnight observations there were people keeping places for one another[1]. In a field experiment it was possible to insert an additional person into a waiting line and to record where an objection came from[2]. Neither operation is straightforward when only one person remains. A solitary customer can have waited a long time without ever having someone ahead or behind whose place they could take. The uncertainty concerns a collective noun. There is little uncertainty about whether the customer is visible.

Several properties of ordinary queues make them suitable for examining the time course of a group judgment. A departure after service removes a member from the queue. Members need not speak or know one another. Their relative positions are informative, although much of the time the people at the back are standing still and much of the motion in the room belongs to people passing by. Research on entitativity distinguished evidence that people form a group from the inventory of people within view[3]. The geometry of two facing bodies alone can affect their recognition[4]. At a counter, by contrast, the people in line may all face the same way, and evidence that they belong together can arrive several seconds apart.

Observers extract social relations from sparse trajectories[5,6]. If a group judgment requires access to a relation between at least two currently visible bodies, reducing the set to one should largely abolish the contribution of the earlier trajectories. A second possibility is that the observer interprets the stationary body by reference to an event. In event segmentation accounts, what just happened can determine which event model is available for interpreting the next observation[7,8]. A third possibility is linguistic. A person buying a ticket may report a queue at a familiar window even on a day when nobody has come. In a survey of floor-plan descriptions, respondents sometimes used the word for an area that an architect had left unoccupied[9]. That use has much in common with calling a vacant room a waiting room.

These possibilities make different predictions in a restricted case. If the history effect depends on treating the remaining person as a member, it should disappear with that person. If the history supplies a name for the place, the departure of the last person need not erase the difference. We first estimated a history effect with one person in view, using a question that specified the time of judgment but left the word *queue* undefined. We then estimated it again with zero people in view. Each participant answered the queue question once. Asking the question twice would have made the boundary under study obvious on its second appearance.

A queue with one remaining person

The films showed an oblique view of a small hall with a counter and two open doorways. Five figures were visible at the start. In the ordered history four people approached the counter in turn, then left. The fifth advanced each time a place became available. In the passing history the four crossed the hall on a path beside the counter. The fifth covered the same distance toward the counter and came to rest on the same frame. Both films ended with the same person in the same hall. We refer to the histories by their arrangement in the animation. The only occurrence of the word *queue* in the experiment before the response was in the question itself.

We assigned 720 observers equally across two histories and three intervals between the end of the animated sequence and the question. During the interval the last frame stayed in view. At the middle interval, two seconds, 85 of 120 observers in the ordered condition and 45 of 120 in the passing condition answered yes to "Is there a queue in the room now?" The difference was 33.3 percentage points (95% interval 20.9 to 44.3). Counts for all six cells appear in Table 1. A yes response after the passing

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history was quite ordinary. In that film somebody did approach the counter and wait there.

Table 1 | Affirmative answers in experiment 1. Each history has 120 different observers per row. The last column gives the ordered minus passing difference in percentage points with a 95% score-based interval.

Final frame held (s)	Ordered	Passing	Difference (95% CI)
0.5	91	46	37.5 (25.2 to 48.1)
2	85	45	33.3 (20.9 to 44.3)
8	74	42	26.7 (14.1 to 38.1)

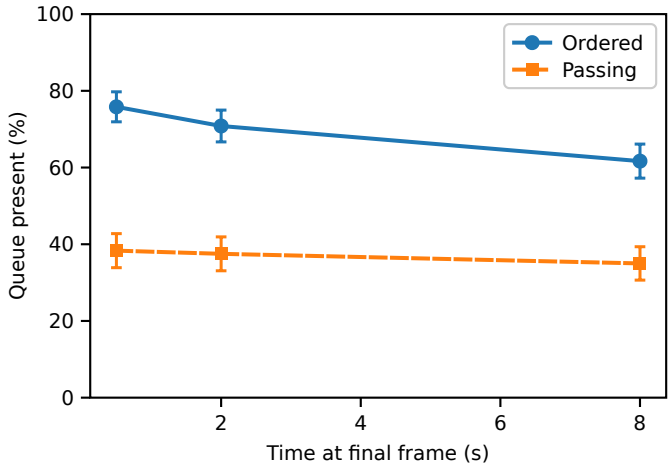


Fig. 1 | Queue judgments during the stationary interval. Points give the percentage answering yes, with one binomial standard error. Each point represents a separate group of 120 observers. Lines connect the three tested intervals.

Between the shortest and the longest hold, the estimated difference fell by 10.8 points (Fig. 1). Each interval was tested on fresh observers, and the uncertainty in a change of two differences is appreciable. The approximate 95% interval for the decline was −6.0 to 27.7 points. In particular we have no estimate of an individual observer's time to stop calling this a queue. The positive contrast at eight seconds is evidence about judgments made after eight seconds of looking at the stationary display. It gives no evidence about what happens after leaving the room and coming back.

The halls differed slightly in the alignment of the door and the counter. At two seconds every hall yielded more affirmative responses after ordered service than after through traffic (Fig. 2). Fifteen observers contributed to each tile. Hall F, for example, drew twelve yes answers after ordered service and eight after through traffic. One could infer from that column alone that the hall was a particularly convincing place to wait even in the absence of a line. With only fifteen observers in that condition, the high rate could also reflect who happened to see hall F.

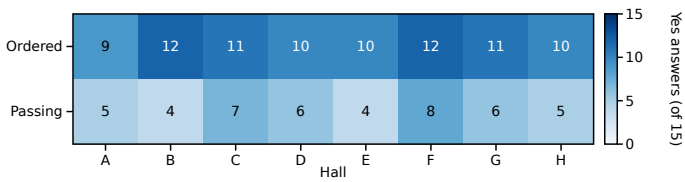


Fig. 2 | Answers at two seconds for each of the eight halls. Entries are counts of affirmative answers out of fifteen. Each column shares a terminal image.

Clearing the room

The solitary person in the first experiment supplied a material link to the earlier line. Object-file experiments supply a familiar case in which information about a moving object remains available when the scene around it has changed[10]. Even a substantial interruption in visibility need not prevent tracking the same item[11]. A lone customer may likewise carry the description of what they were doing a moment earlier. No corresponding individual can carry that description in an empty room.

We made a second set of films for a new sample of 448 observers. The final portion of the film either left the fifth person by the counter or showed that person walking out. The question appeared two seconds after the last motion. The wording, the eight halls, and the instructions matched the first experiment. A count question followed the queue judgment. We used a count question at this stage because a participant could take the prompt to refer to the queue seen a moment earlier, or simply miss the exit of the last person. The second error would be visible in a report that someone was still in the room.

Table 2 | Queue judgments in experiment 2. Each row has 112 observers. Count answers were collected after the queue judgment. The rightmost column gives the joint count for both responses.

Persons left	History	Queue present	Count correct	Yes and count correct
1	Ordered	77	108	75
1	Passing	41	111	40
0	Ordered	28	109	27
0	Passing	12	110	12

For films with a remaining person the estimated difference was 32.1 points (95% interval 19.2 to 43.6), close to the 33.3 points observed at two seconds in the first experiment (A queue with one remaining person). In the empty hall the corresponding difference was 14.3 points (4.3 to 24.1). Most viewers of the empty hall answered no under either history. In the ordered condition one person in four endorsed a queue in the empty hall. This estimate refers to a single presentation of the question, with no preceding judgments to teach participants what the experimenters would accept as a queue.

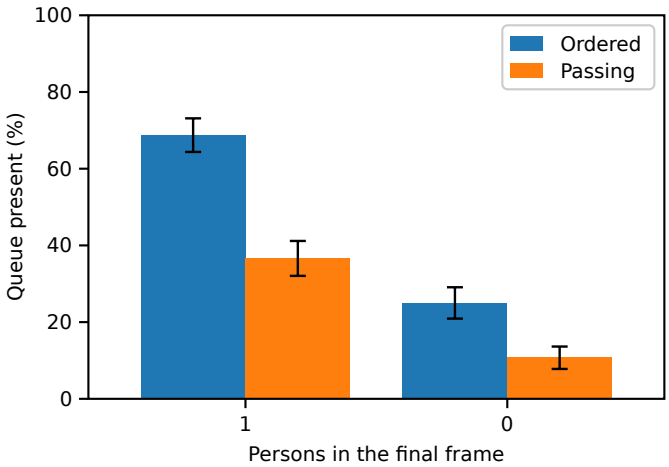


Fig. 3 | History and occupancy in experiment 2. Bar heights give the percentage answering yes to the queue question. Caps are one binomial standard error over 112 independent observers.

The change in the ordered-minus-passing difference on removing the last person was 17.9 points (approximate 95% interval 2.0 to 33.7). The interaction in Fig. 3 has a simple interpretation on the probability scale. A history of taking turns had less influence on judgments at an empty counter than at an occupied one. Removal involved an additional movement and an uninterrupted view of an empty hall. We cannot assign the interaction separately to those aspects of the manipulation. The direction also depends on the measurement scale. The ratio of the two small proba-

bilities for an empty hall exceeds the corresponding ratio for an occupied one.

Thirty-nine of the forty affirmative respondents who saw an empty hall reported zero people. The other respondent reported one. Of the 184 negative respondents in the same two conditions, 180 reported zero. An erroneous count cannot on its own explain the result in Table 2. Correctly answering the second question does not guarantee that the respondent had counted the people at the time of the first. The final frame remained on screen for both questions. A participant could reconsider the scene, or count for the first time, as soon as we asked for a number. The joint frequencies tell us that a queue judgment and a count of zero could be given in succession without any change to the room.

Discussion

The effect of the film's history survived a considerable reduction in the evidence available at its end. In the one-person condition some continuity was possible through an individual. In the zero-person condition the spatial arrangement of the remaining fixtures was all that survived on screen. An account based solely on the features of those fixtures would give the same response distribution after either history. So would a rule under which a viewer always counted the visible people and then applied a fixed minimum number for a queue. Both accounts require an additional history-dependent term to accommodate the differences between columns of Table 1 and between histories within each occupancy in Table 2.

One reading is that people retain a short episode of taking turns as a unit. The departure of one person is a particularly poor signal that the episode has ended. It is what usually happens while it is in progress. By design the last departure in the empty condition begins in much the same way as any of the preceding departures. Evidence that *this* departure was the last consists partly in the ensuing absence of the next customer. That evidence needs time to accrue. There are accounts of event boundaries in which the observer revises an ongoing interpretation when predicted activity fails to occur[7]. Our delays set a lower bound on how long history can affect the distribution of reports under uninterrupted viewing. They tell us little about the mechanism that carries the history through the interval.

A different reading is available without supposing that anybody experiences a queue as continuing. The word can pick out a location with a use, as in directions to join the queue on the left even if the left-hand counter has yet to receive a customer. A person who saw four people served successively had evidence about that use. The people in the passing film provided much weaker evidence. A participant could therefore remember the film quite accurately, understand *now* to mean the time of the question, and choose the place reading. Work on graded category membership suggests caution in setting necessary conditions from the most familiar examples of a category[12]. Here even the type of thing being classified may differ between respondents.

If most affirmative respondents had counted one or more people, a residual impression of an animated figure would have been a sufficient explanation. What forty people did with the word *queue* deserves attention, but attributing the result to a failure of object tracking would require an additional account of their subsequent counts. Conversely the count cannot settle whether those forty people understood the question to concern a queue that someone could join. No one was asked to enter the room.

There is a related problem of scope in asking about the last frame of a film. Viewers routinely summarize a film to a listener who has seen less of it than they have. A queue is an informative thing to report about the ordered version, even to a listener whose question is more specific. An instruction emphasizing the current picture may reduce the incentive to supply such a summary. It cannot remove that incentive altogether[13,14]. We deliberately used a single short question and accepted its ordinary range of readings. A forced choice between "a place to queue" and "people queuing" would address a different question. It would be quite a good follow-up among respondents who endorse the empty hall, provided it came after their initial answer.

Another possible source of persistence is an inference that the people are still in the building and might return. Both versions showed the same doorways, and in the empty conditions all five figures passed completely beyond the image. There was no cut that could have removed a person still standing by the counter. A doorway does, however, leave open the possibility of another arrival. An observer who had inferred a regular service might expect the vacancy to be brief. Expectations of that kind concern what the counter will be used for in a few seconds. On our measure they cannot be distinguished from memory for what it was used for a few seconds ago.

The halls contain neither barriers nor signs specifying the function of the counter. That choice removed a source of answers that could have been given from the final frame alone. It limits the claim quite sharply. In a hall with a permanent channel of rails a respondent has a perfectly good stationary object to refer to after all the people leave[9,15]. At the other extreme, a queue for a bus on an unmarked pavement has no corresponding structure. Nor does agreement on the English word guarantee agreement about the persistence of the group in a language which uses different words for an arrangement and an act of waiting. We used the same noun with the same recruitment population in both experiments. Its interpretation elsewhere remains an empirical question.

For that reason the numerical effect has a fairly local meaning. It is the extra fraction of affirmative reports one would expect by showing service rather than passage before holding a particular set of terminal images on screen. We would hesitate to give these queues a lifetime. The question that the present data leave most exposed is whether, among those who say there is still a queue in the empty room, anyone thinks it currently has a front.

Methods

Observers and allocation

Adults living in the United Kingdom who used English daily took part individually at a terminal with a physical keyboard. Recruitment at community testing rooms in Bristol and Bath used the description "short judgments of animated scenes". The experimenter could explain the response keys before starting the session and then moved behind the partition. Participants consented in writing. The research committee of the Merewick Institute approved the protocol (MI-24-19). People who had attended the drawing pilot or completed the first experiment could not take part in the second. A name check at booking was separate from the anonymous session record.

The target was set in advance in multiples of eight, the number of halls. We chose 120 observers per history and hold for the first experiment. For independent proportions near one half this gives a nominal 95% half-width of 12.7 percentage points for a difference. We regarded that precision as sufficient to distinguish a shift of one third from a small fluctuation. In the second experiment resources allowed 112 per history and occupancy. Its four-cell interaction was always going to be less precise than a comparison of two of the cells. We fixed the sample sizes before looking at the responses. Participants received the same flat session payment whichever key they pressed.

A practice task with a moving square preceded allocation. Participants had to indicate when it stopped and then read the prompt back to the experimenter. Of 731 people who consented in the first experiment, six withdrew during practice and five could not read the prompt at the viewing distance they preferred. In the second experiment 454 consented, three withdrew and three could not read it. The remaining 720 and 448 received allocations and all gave a primary response. The practice task contained no people, counters or questions about social activity. Neither speed on practice nor speed of the eventual response entered the analysis.

A shuffled list contained every combination of hall and condition once per block. Experiment 1 used fifteen blocks of 48 allocations, experiment 2 fourteen blocks of 32. Both venues drew from one list per experiment. The terminal took an allocation only after practice, and recorded the film

identifier together with the response. At that point the operator had no further input. No participant saw a second version of a hall. Exposing an observer to both versions would make clear that the investigators had some interest in the people who had disappeared. A balanced repeated design would buy precision at the cost of that information.

Preparation of the films

The rooms were plan-oblique drawings, all from the same elevation, on a neutral field. Each contained one counter reaching from the side wall part of the way into the hall. Four drawings had the counter against the left wall and four against the right. Two widths and two distances from the exit gave four drawings per side. We used a solid front and a narrow top surface for the counter. There was no attendant, writing, rope, floor arrow or cash register. A gap beside the far end of the counter allowed a figure to pass to the exit after reaching it. A separate route along the opposite wall led to the same exit. It was visible from the start in all versions.

The five figures had an elliptical head and a shoulder line, drawn at the same scale throughout the film. A slight asymmetry of the shoulder line marked their facing direction. The four figures that ultimately disappeared had slightly different gray coats so that the order of departure could be followed. The fifth wore a darker coat. A check on eight-bit values of the exported frames gave the same coat and background values at every location in the common terminal image. The darkest coat did not identify anyone as a queue member, since exactly the same coat was present in both histories. It did make the trajectory of the final person easier to follow than those of the others.

In the ordered version four people stood at successive places ahead of the dark coat. Each in turn paused at the counter and walked away through the gap. Those behind advanced by one place. For the passing version we displaced the first four paths across the width of the hall so that the counter no longer lay on their route. They were staggered across that route, with pauses in the same epochs as the service pauses. The dark coat retained its path, advancing in steps toward the counter under either history. Participants in the passing condition could consequently have read that motion as waiting behind a group taking an unusual route. To the extent that they did, this comparison understates the contrast between an unambiguous queue and unambiguous unrelated activity.

We matched the number of figures, the time of the four exits, and the duration of the dark coat’s steps across histories. We did not match local motion energy around the counter. Such a match would remove some of the evidence that the other four had taken turns there. The ordered film also placed the coats closer together at the start. Thus the treatment is a history of organized service as a viewer might encounter it. It does not isolate serial order from proximity or from whether the figures passed near the counter. The endpoint check controls any account that depends entirely on differences visible after the last step.

Timing and prompts

A fixation mark preceded the movie by 750 ms. The first frame then remained stationary for one second before the four successive departures started. The display advanced at 30 movie frames per second on a 60 Hz screen. We used an orthographic view and fixed the camera. There was no zoom toward the last person or toward the empty floor. The time coordinate used in Fig. 1 begins at the first frame following all motion and excludes the time spent walking out. Sound was off. At the end of the assigned hold the question appeared in the margin, outside the room. The picture stayed still until the observer made a choice.

For experiment 2 we added a common two-second segment beyond the point reached in experiment 1. In the occupied version the remaining person stood in place during this segment, with a small weight shift ending on the final frame. In the vacant version the same figure turned and used the side gap to leave, disappearing completely just before the final frame. Both movies then held the endpoint for two seconds before the question. The terminal image for the occupied version was the one used in experiment 1. Consequently the occupied arm repeats the history contrast at the same time since motion ceased, with a somewhat longer residence at the counter. We report it separately. The weight shift controls the time of the last movement but provides no match for its distance or for a departure’s significance.

A yes and a no key were marked on the keyboard. An assignment independent of the movie used either the left key for yes or the right key for yes, with the mapping printed beside the question. There was no response deadline. Following the primary answer in experiment 2, the margin text changed to “How many people are in the room now?” and the participant could type an integer from zero to five. The second question did not mention the previous answer and there was no opportunity to revise it. The count probe ended the task. Staff could discuss the film with participants after their responses had been stored.

Estimates and uncertainty

Let $Y = 1$ denote a yes response and h a hall. The primary comparison for experiment 1 was the difference at the two-second hold. The other holds were planned descriptive comparisons. For experiment 2 the specified comparison was the history difference with nobody present. Its comparison to the occupied condition was secondary. At each endpoint t the reported estimate was

$$\widehat{D}_t = \frac{1}{8}\sum_{h=1}^{8}\left(\frac{y_{h,o,t}}{n_{h,o,t}} - \frac{y_{h,p,t}}{n_{h,p,t}}\right). \tag{1}$$

Here y is the number of affirmative answers, n the number assigned, and o and p stand for the ordered and passing histories. Equal allocation makes equation (1) equal to the difference of the two pooled proportions. We report it in percentage points. We chose that scale because it gives the expected change in the number of yes answers per hundred viewers. The count probe was descriptive and entered neither the numerator nor the denominator of the primary contrast.

Intervals for the differences use Newcombe’s uncorrected combination of Wilson score limits for independent proportions[16,17]. They treat the pooled arm counts as binomial counts. For fixed balanced halls with differing probabilities this is an approximation which can overstate the sampling variance. We give the hall counts for the primary comparison of experiment 1 to show the size of the item variation. We did not sample the eight halls from a defined population of buildings. Inferences across observers for these images have better support than inferences across possible images[18]. None of the intervals has been adjusted for the number of descriptive comparisons.

For a change in a history effect across two independent endpoints, the sign attached to a term reverses between endpoints but its contribution to the variance does not. We used the approximate standard error

$$s_{D_a - D_b} = \left[\sum_{t\in\{a,b\}}\sum_{g\in\{o,p\}} \hat{p}_{gt}(1-\hat{p}_{gt})/n_{gt}\right]^{1/2}. \tag{2}$$

We used 1.96 standard errors on either side of the observed change in equation (2). The bars in the figures show one standard error for the individual proportions. Comparing those bars by eye gives neither of the difference intervals in the text. Analyses used all primary responses as allocated. In particular, a mistaken count on the later probe cannot retrospectively remove a yes or no answer. Filtering on that probe could select different kinds of observer after the two different movies.

Data availability

The counts required for the reported between-condition comparisons are in Table 1 and Table 2. The hall-specific counts for the first experiment’s primary endpoint appear in Fig. 2. The signed consent records contain no links to individual responses. The stimulus drawing instructions and timing conventions below describe the parts of the films that enter the comparison.

Terminal frames and timing checks

The eight halls came from a single drawing sheet. Reversing the sheet reflected the counter and both paths. The reflected version had the same gap and the same order of departures. We did not reflect text or signs, since there were none in the image. Within a hall the terminal background was a single stored frame used for every history. For the occupied endpoint the compositor placed the same coat on the same anchor pixel of that background. In experiment 2 it retrieved the stored background alone for the empty endpoint. The prompt was drawn separately. Reusing the composite at the time of the question eliminates residual differences between the final poses[19].

Table 3 | Time convention at film export. Frames in a hold were literal repeats. At 30 frames per second the durations below specify movie time, excluding fixation and any time taken to answer.

Segment	Experiment 1	Experiment 2
Initial view	30 frames	30 frames
Approaches and first four departures	240 frames	240 frames
Final movement segment	absent	60 frames
Hold before the question	15, 60 or 240 frames	60 frames

The exporter assigned the final pose to frame zero of each hold. Thus the two-second interval in Table 3 corresponds to sixty displays of the terminal image before any response text appeared. It was not a two-second blank retention interval. Even a person who looked away during the departures could inspect the current room again at the moment of choice. In developing the materials we tried a blank interval followed by the question alone. People answered those trials as memory questions, sometimes describing the full complement of five coats at the start. We dropped that arrangement before collecting either sample.

What counted as departure was specified geometrically. A figure disappeared only after its coat had passed the outside edge of the doorway. The empty terminal frame contained no visible sleeve or shadow. Some viewers might still have considered the departed customer to be immediately on the other side of the wall. To count as an error on the probe they would have had to put that person *in the room*. We cannot tell from the integer zero whether a participant expected the person to return.

Reading the joint counts

The marginal frequencies are sufficient for the main contrasts because the two answers of a given person were never treated as independent people. For completeness, consider the empty ordered condition in Table 2. Twenty-seven people said yes and counted zero, one said yes and gave another count, 82 said no and counted zero, and two said no and gave another count. In the empty passing condition the corresponding numbers were twelve, zero, 98 and two. No answer is logically inconsistent under the place reading of the question. For this reason we use “correct” only for the count probe.

One could estimate a difference restricted to observers who subsequently counted zero. It would amount to subtracting $12/110$ from $27/109$, or 13.9 percentage points. Its agreement with the 14.3-point estimate for all assigned observers reflects how few counts were mistaken. The restricted comparison selects the observers using an answer given after treatment. For questions about erroneous counts the joint table is the more direct record.

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