First deliverables and milestones – Work packages 1, 2 & 3. (First version January 2016)
NEW: added Work packages WP3b & WP4.
– This version: Final version March 2017 –

WP*i*.1: Formulation of the specific experiments of the WP.
(*i* = 1, 2, 3, 3b and 4).

Contents:

1. Relevant aspects of the SMARTMASS project

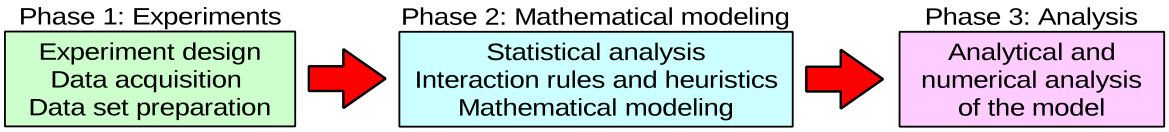
The SMARTMASS project was designed to be carried out in the research group of G. Theraulaz in the CRCA (Centre de Recherche sur la Cognition Animale) of the University Paul Sabatier of Toulouse. The groups originally involved in this research include the Laboratoire de Physique Théorique (LPT) and the Laboratoire d'Analyse et d'Architecture des Systèmes (LAAS), from the same university.

Noticeably, six months before starting the specific Marie Curie action SMARTMASS, the research group above mentioned started to collaborate with the Institute for Advanced Study in Toulouse (IAST) and the Toulouse School of Economics (TSE) in the framework of a joint interest on the multi-disciplinary study of emergent phenomena in humans. This collaboration has provided the research group with a deep experience in disciplines such as decision making and game theory, together with a wider field of vision and a wider range of facilities to carry out the experiments.

Not less noticeable has been the fact that the group of the LPT has assigned a Ph.D student, Bertrand Jayles, who is now in his second year, to this research. B. Jayles has already carried out a series of experiments about collective estimation in Japan during the summer of 2015. A replicate of these experiments will be carried out in Toulouse (at TSE) in March 2016 (finally June 2016).

2. Recall (*from the original project*): the three Work Packages

WP1: Optimizing individual decisions within a group
WP2: Collective decisions in pedestrian crowds
WP3: Information processing in segregation of pedestrians
NEW: WP3b: Characterization of human walk in groups in a small circular arena
NEW: WP4: Collective search for information



WPs are carried out simultaneously and consists of three consecutive phases:

3. Experiments: formulation, protocols, start-up

WP1: Optimizing individual decisions within a group

Recall– *In a series of experiments, we will investigate the cognitive processes and the individual interactions when a group is confronted to several possible choices. One task consists in guessing the unique box able to contain exactly a set of e.g. 500 marbles initially scattered on a flat surface. The influence of the knowledge of (part of) the other individuals' choices, or the advice of experts (the organizers) will be studied. This experiment will permit to (i) quantify how a given information (and its difference from the actual solution) affects the choices, and (ii) determine the ability of individuals to retain or discard an information (true or false!) which seems to differ from their initial guess. The aim is to identify which combination of public/private information optimizes the ability of the group to find the best solution. Previous works doing similar experiments didn't investigated the effect of different kind of information on subjects' choices.*

A first series of experiments has been carried out in Japan during summer 2015 by B. Jayles. Preliminary results have been used to elaborate a second protocol for a new series of experiments that will be carried out in Toulouse in March 2016 at the Toulouse School of Economics (TSE).

We present here this second protocol.

Participants are first asked to sign a free consent of participation. This is the first step in all the protocols. They are then invited in groups of 10 to a room with 10 work-stations. Each work station is equipped with a laptop, a mouse, a pencil, a sheet of instructions and some white sheets. Work stations are isolated from each other with large vertical panels in such a way that participants can not interchange visual information (see Fig. 1).

Fig. 1. Left: work station nº8. Right: participants in their work station, doing the experiment.
Pictures form our own experiments, carried out in Toulouse (TSE), from 29 February to 04 March 2016.
(Added to the text in a revised version –20 March 2016)

Each session of 10 participants would lasts around 90 minutes; participants are confronted to a series of 35 questions involving numerical estimation of different magnitudes (distances, lengths, and other quantities).

Here are some representative examples:

- How many marbles do you think there is in this glass? (picture presented)
- What is the distance between Paris and Tokyo?

- What is the number of cell phones sold in France during 2105?
- What is the average number of kilometers that professional cyclists do during one year?

Worth mentioning is the inclusion of questions without defined responses such as “How much does a zorglub cost?”; the idea is to test if pure estimations are measurable, where 'pure' means 'exempt of cultural references or biases'.

For each question, participants have 40 s to give a first guess. Then, they are provided with *some* information about the average guess of previous subjects. The average is calculated among the previous k subjects (k = 1, 3, 5, 7, 9), but participants are not informed about how this average is calculated, nor about how many subjects are considered in the average. After that, they are asked to give a second guess, within a limited time of 40 s. Finally, and also for each question, they are asked to provide information about (1) their level of confidence in their answer, (2) their opinion about how pertinent was the collective guess, and (3) their age and sex (information that is kept anonymous). Participants are informed that they will be paid according to their performance.

We have programmed 20 sessions. The idea is to observe some convergence along the sessions, as predicted by our first observations in the experiments carried out in Japan. Participants must be naive; they can not participate in more than one session, so a total of 200 participants has to be considered. Recruitment is therefore not the less challenging part of the experiment!

Participants are paid according to their performance: the two best performers receive 20€, the following 4 best performers receive 15€, and the last 4 receive 10€.

The (maximum) total cost of the experiment is thus 20 x (2x20 + 4x15 + 4x10) = 2800€.

Sessions last around 1 hour 30 mn. We plan to do 2 morning sessions and 2 afternoon sessions, *i.e.*, 4 sessions per day along 5 days (in the same week).

Coordination of laptops and data collection is performed with ZTree software (a fast and flexible text-mode file/directory manager freely available).

→ See the attached PDF files for extensive details:
- protocoleJAPON.pdf, Bertrand Jayles (in English)
- protocoleTOULOUSE.pdf Bertrand Jayles (in French)
- InstructionsTOULOUSE.ppt R. Escobedo (in French)

Cultural effects are to be expected. Experiments that took place in Japan were obviously carried out in Japanese. Differences will come not only from the adaptation of questions to French culture (e.g., “number of inhabitants in Tokyo” will become “number of inhabitants of Paris”, and “number of inhabitants in Bayonne” –asked in Japan– will be “number of inhabitants of Toyohashi”), but also from variations on the degree of self-confidence and the perception of collective guesses.

For this reason, we are planning to carry out a third series of experiments in Bilbao (Spain), where the secondment of the SMARTMASS project will take place.

November 2016: This plan has been replaced by a third series of experiments in Toulouse where we plan to extend the study to the case where experts provide information of different category (*e.g.* false information).

WP2: Collective decisions in pedestrian crowds

Recall– *In a series of experiments, we will study how mimetic behaviors, physical interactions between individuals, various information sources, and past experience affect the decisions of pedestrians walking in a circular corridor including a bifurcation. The N pedestrians (with N = 30 and 60) will be asked to choose the passage they estimate to have been the less often chosen by the others in a given time period, and will be rewarded for each correct guess. We will study the case where the pedestrians benefit from (i) no information on other people's choice, and (ii) a partial information true or not about the choice of n ≤ N pedestrians. The effect of the density of pedestrians, which will control the information gathered by an individual from observing the behavior of other pedestrians ahead of him/her, will also be investigated.*

The approach of this series of experiments has experimented an abrupt change with respect to what has been carried out before: we are planning to use virtual reality!

Virtual Reality (VR) has recently become affordable to common use, thanks to the adaptation of VR glasses to the recent smartphones. Previously VR devices were based on expensive computational platforms.

Fig. 2. Samsung Oculus GEAR VR (left) and Samsung smartphone coupled to the glasses (right).

We are planning to use 10 of these devices to reproduce a corridor with an arbitrary number of bifurcations at which pedestrians will have to make a decision about which of the two sides has been the less frequently chosen by the preceding pedestrians in a given period of time.

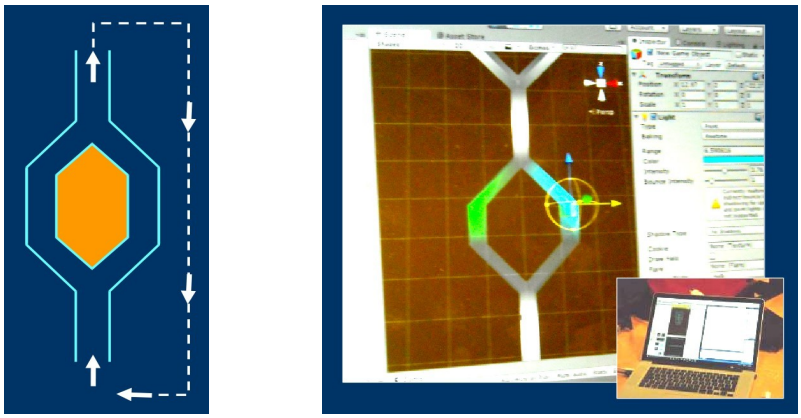


Fig. 3. Virtual corridor with *infinite* bifurcations:
theoretical design (left) and implementation in software *Unity* (right)

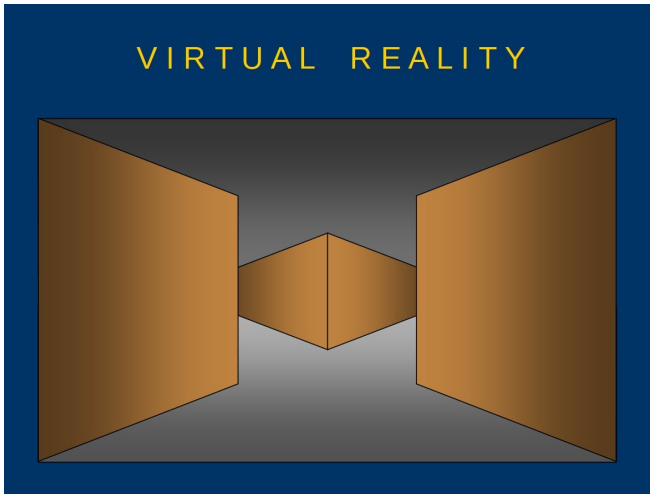


Fig.4. Arrival to a bifurcation. (Virtual!) Pedestrians will have to make a decision, go right or go left, according to the information they receive and in a limited time. Participants will be rewarded in function of their performance, *i.e.*, the number of right choices.

Participants are seated in rotating chairs. Chairs rotate along the vertical axis but can not move horizontally. Once participants are in the virtual world, they move forward with a constant speed of about 1m/s (standard walking speed). Information about the frequency of use of each side of the bifurcation is provided by means of the degree of colors of the walls of each side of the bifurcation. For example, from green (low frequency) to blue (high frequency).

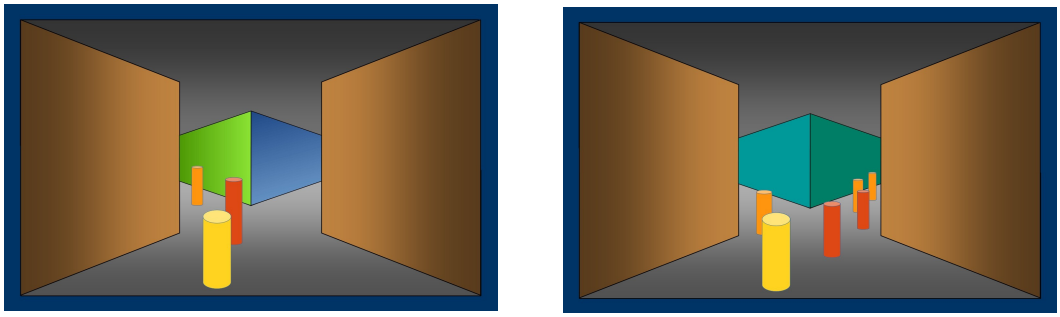


Fig.5. In the bifurcation shown in the left panel, the choice is clear because the difference between the green an the blue is large enough: the yellow player has to take the left corridor, even if the two preceding subjects make the same decision. However, the green-to-blue gradient in the bifurcation shown in the right panel is slightly in favor of the right corridor, while at least 4 subjects have already taken this way. These two sources of information induce a conflict in the decision which must be solved under a certain level of pressure, as (virtual) pedestrians move with constant speed and therefore have a limited time before reaching the bifurcation point.

VR constitutes a powerful experimental instrument with important benefits. A crucial benefit is the possibility to reproduce *exactly* the same experimental environment, with identical conditions for all participants, wherever they are and whenever they do the experiment. Another benefit is that an arbitrarily large number of subjects can participate simultaneously, both real (with several glasses) and virtual (reusing the data from real subjects), thus simulating crowds. It is also possible to make subjects to interact with subjects (or groups of subjects!) that behave exactly like him/her. Moreover, the scenario can be changed in real time (no comparison with the effort of re-adapting real scenarios, made of large and heavy panels of 2.5m high and several meters long).

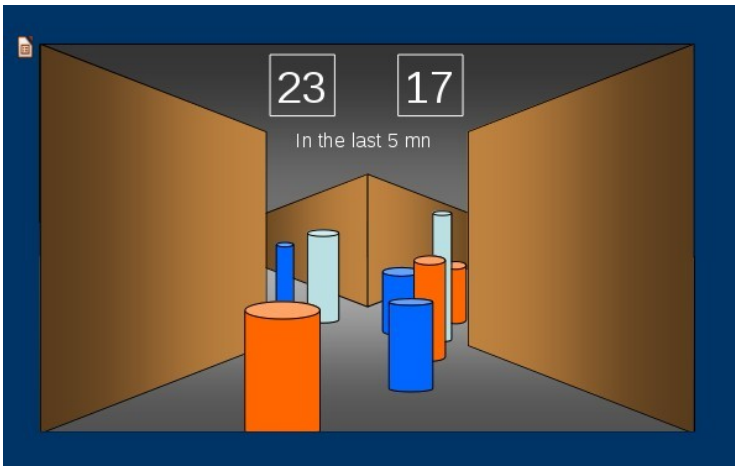


Fig. 6. Information can be made more complex by adding panels with numerical data. Here numbers correspond to the number of pedestrians that have taken each corridor (23 pedestrians went to the left, 17 went to the right) in the last period of time of 5 minutes. The subject should integrate this information with the environment, where 5 subjects seem to go to the right, and 2 to the left.

VR experiments are a pioneering research area. The specific environment of these series of experiments is being developed in collaboration with the Max Plank Institute for Ornithology of Konstanz (Germany) and the group at LAAS in Toulouse, with the software *Unity*, a cross-platform game engine used to develop video games (*Wikipedia-en*).

The detailed description of the experimental protocol is presented in the document
"2.CouloirVirtuel-ProtocoleProvisoire-03May2016".

– June 2016:

Unfortunately, the data collection process which should have provided the data text files with the individual decisions of each participant in each experimental condition was unexpectedly extremely complicated to set up and could not be implemented during the time covered by the action.

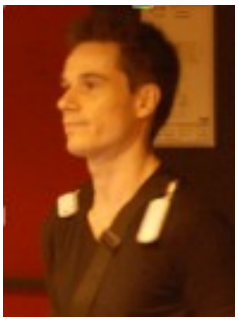
These technical difficulties started to introduce important delays in the schedule of WP2, so that, taking profit of the exhaustive meetings we had about how to approach this WP, we decided to implement an alternative environment where subjects have to make individual decisions depending on the information left by preceding subjects (as in the corridor). This lead us to the implementation of WP4, whose experimental phase is planned for the first week of May 2017. See WP4 for more details.

The project of carrying out the WP2 with Virtual Reality is however still active, and at the moment relies on the expected arrival of R. Bastien (from the above mentioned Max Plank Institute) to the CNRS, at Toulouse, hopefully in 2017.

WP3: Information processing in segregation of pedestrians

Recall– *The experiments will involve pedestrians in a hall. They will be assigned a color (red or blue) only known to them. The aim of the experiment is to observe the segregation of the pedestrians in two groups, as they progressively identify the other's color thanks to: (i) a private sound signal delivered from a portable electronic device telling them the majority color in their immediate neighborhood (the N = 1, 2 or 3 first neighbors), (ii) public information on LCD screens, and (iii) the presence of a few pedestrian with a color known to everybody (but then, each one initially ignores his own color).*

These experiments were carried out in September 2015 in the “Salle Le Cap” at the University Paul Sabatier in Toulouse, along one week, and involved around 60 persons (some people participated in more than one session).



Participants were “tagged” with two emission/reception devices (one in each shoulder, called 'left and right tags'), and asked to walk under certain conditions in a circular arena drawn on the floor (see figs. 7 & 8).

There were height kinds of sessions, according to (I) the number of participants: 1) sessions with one pedestrian, 2) sessions with two pedestrians, and 3) sessions with 22 pedestrians, and (II) the size of the arena.

Fig. 7. Bertrand Jayles holding the tags.

1) Sessions with a single pedestrian were planned to measure the interaction of pedestrians with the limits of the arena. We use three different sizes of arena, whose radii were R1= 1.78 m, R2=2.52 m and R3=3.56 m. Participants were asked to walk randomly in the corresponding arena, avoiding to walk too close to the border (<10cm), for an approximate time of 3 minutes.. We performed 20 sessions per kind of arena, for a total of 60 sessions (total duration of experiments: 180 minutes).

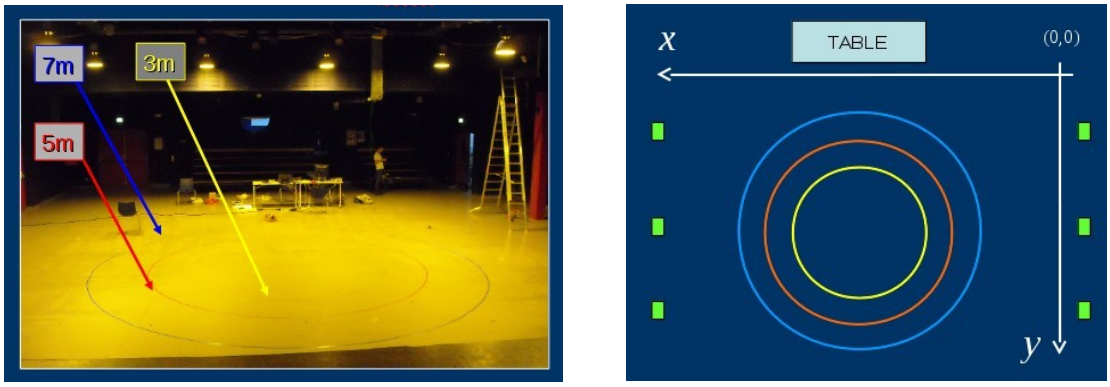


Fig. 8. Left: Salle Le Cap (Université Paul Sabatier, Toulouse), showing the diameter of the three arenas. Right: Sketch of the experimental set-up with the three arenas, the location of the captors (six small green boxes) and the system of coordinates to calculate the position of the pedestrians.

2) Sessions with 2 pedestrians were devoted to measure the interactions between pedestrians. Once the interaction pedestrian-wall is known, we expect to characterize the pedestrian-pedestrian interaction in each arena size. We performed 10 sessions per arena size, for a total of 30 sessions, so 90 minutes (total duration of experiments: 90 minutes).

3) Sessions with 22 pedestrians constitute the real experiment. Only the large arena of radius R3 was used (see fig. 9). Each time there are new participants, pedestrians are informed that they are divided in two groups, reds and blues, and that their goal is that, at the end of the session, they have reached a position in which their environment consists mainly on individuals of their own group. They are informed that the two devices they hold serve both to capture their instantaneous position and to produce an acoustic signal (a regular beep) if their environment is not the adequate. Participants are not informed about their own color. They also ignore how the environment is exactly defined, and that the groups are randomly selected in each session.

Fig. 9. Session of 22 pedestrians walking randomly in the largest arena (blue circle).

The procedure is then explained, in the following way: “We will ask you to walk randomly during around 45 s in the largest arena. We specifically ask you not to pay attention to the smaller arenas, not to run, and of course not to talk with other participants. After these 45 s, some of you will hear an acoustic signal, which would mean that your environment consists mostly of people from the other group, so that you will have to move until the signal stops. Once everybody has ceased to move and no beep is heard in the whole group, the session will be stopped” (see fig. 10).

Fig. 10. Final state of a session: all pedestrians stand still and no beep is heard

The instantaneous environment of a pedestrian is defined as the set of the first *k* neighbors of the pedestrian. The acoustic signal is thus sent if the majority of the first *k* neighbors belongs to the other group. The number *k* takes odd values, so that there is always a majority: if [*k*/2]+1 neighbors are from the other color, a beep is produced (approximately each 0.5 seconds) –here [*x*] denotes the entire part of a number (*e.g.*, [2.5] = 2).

We performed 120 sessions of 22 pedestrians, in groups of 6, for *k* = 1, 3, 5, 7, 9 and 11. This means that we had 20 sessions for each value of *k*. As an example, note that if *k* = 5, then as soon as 3 of the first 5 neighbors of a pedestrian are of a different color than the pedestrian, the tags will produce the acoustic signal.

3	IND		CODE	Time	k	Nº Tags	Excluded
11-12h	1410	Move	E1S2R1	09-15-2015 10:58:45	1	1—23	8
	1411	Segr	E1S2R1	09-15-2015 10:59:43			
	1412	Done	E1S2R2	09-15-2015 11:00:16			
	1413	Move	E2S2R1	09-15-2015 11:00:27	3	1—23	8
	1414	Segr	E2S2R1	09-15-2015 11:01:20			
	1415	Done	E2S2R2	09-15-2015 11:01:59			
	1416	Move	E3S2R1	09-15-2015 11:02:07	5	1—23	8
	1417	Segr	E3S2R1	09-15-2015 11:03:07			
	1418	Done	E3S2R2	09-15-2015 11:03:42			
	1419	Move	E4S2R1	09-15-2015 11:03:50	7	1—23	8
	1420	Segr	E4S2R1	09-15-2015 11:04:50			
	1421	Done	E4S2R2	09-15-2015 11:05:37			
	1422	Move	E4S2R2	09-15-2015 11:05:41	9	1—23	8
	1423	Segr	E5S2R1	09-15-2015 11:06:43			
	1424	Done	E5S2R2	09-15-2015 11:07:13			
	1425	Move	E6S2R1	09-15-2015 11:07:19	11	1—23	8
	1426	Segr	E6S2R1	09-15-2015 11:08:25			
	1427	Done	E6S2R2	09-15-2015 11:09:25			

Fig. 11. Detail of the third group of sessions, with 18 events, three events (Move, Segregate and Done) per session, with the code of the event, the timing, the value of *k* and the tags involved in the session.

3	IND		CODE	Time	N	Nº Tags	Other tags	R
17-18h	1608	Move	E0S0R1	2015-09-15 16:46:00	1	5		P
	1609	Segregate	E0S0R1	2015-09-15 16:49:21				
	1611	Move	E0S0R2	2015-09-15 16:49:36	2	4, 19	(20)	P
	1612	Segregate	E0S0R2	2015-09-15 16:52:34				
	1614	Move	E0S0R3	2015-09-15 16:52:58	1	20	(4,22)	P
	1615	Segregate	E0S0R3	2015-09-15 16:55:59				
	1617	Move	E0S1R1	2015-09-15 16:56:21	1	4	(12,14,15,20)	M
	1618	Segregate	E0S1R1	2015-09-15 16:59:20				
	1620	Move	E0S1R2	2015-09-15 16:59:51	2	5, 19	(11,12,20)	M
	1621	Segregate	E0S1R2	2015-09-15 17:02:53				
	1623	Move	E0S1R3	2015-09-15 17:03:31	1	20	(12,14)	M
	1624	Segregate	E0S1R3	2015-09-15 17:06:32				
	1626	Move	E0S2R1	2015-09-15 17:06:51	1	5	(20,12)	G
	1627	Segregate	E0S2R1	2015-09-15 17:09:47				
	1629	Move	E0S2R2	2015-09-15 17:10:11	2	19, 20	(12)	G
	1630	Segregate	E0S2R2	2015-09-15 17:13:12				
	1632	Move	E0S2R3	2015-09-15 17:13:51	1	4	(12,19,20)	G
	1633	Segregate	E0S2R3	2015-09-15 17:16:51				

Fig. 12. Third random walk session with one and two pedestrians. There are 18 events, two with one pedestrian, one with two pedestrians, in each kind of arena (radii are P: 1.78m, M: 2.52m and G: 3.56m).

We already started the analysis of the data; preliminary results show that there exist an optimal value of k, which is *k*=9.

June 2016: A second series of experiments.

A second series of experiments was carried out in June 2016 (in the same place, Salle “Le Cap” at UPS, Toulouse), again during one week. Three were the reasons for this new series of experiments: 1) the need for larger data sets for each experimental condition tried in the first series in Sept 2015, in order to improve the quality of our statistical measures and estimators, 2) the extension of the study of the segregation phenomena to qualitatively different experimental conditions, and 3) the collection of (very) large data sets for the specific analysis of human walk, analysis that we decided to afford in a specific Work package, due to the extension of the work it demands.

EMPLOI DU TEMPS

(ce qui a été finalement fait)

		MARDI	MERCREDI	JEUDI	VENDREDI
S1	09:00	Marche aléatoire 1P & 2P (3 Rayons) 1abc, 2ab (3min)	Marche aléatoire 1P & 2P (3R) 4abc, 5abc (3min)	M. aléatoire 1P & 2P (3R) 8abc, 9abc (3min) WIKI COULOIR	Ségr. en 2 GROUPES 4x [k=1,3,...,13] + k Exclusif: 2x [k=2, 3]
S2	10:00	22P – Marche aléatoire 45s + Ségr. classique 1x [k = 1, 3, 5, 7, 9, 11] 20x [k = 13]	22P – k = 3 Décalé: 3x [234, 345, 456] k Exclusif: 5x [k=2], 3x [k=3] + 2x Ségr. classique [k=13]	22P – Marche aléatoire 45s/10s + Ségr. classique 4x [k = 1, 3, … , 11, 13] (une des 4 pendant S3)	5P & 10P Marche aléatoire (sans obstacle) 6x [5P, 10P, 5P]
S3	11:00	22P – Marche aléatoire 3min. avec OBSTACLE 5x Cylindre + 5x Couloir	22P – k Décalé: 2x [234, 345, 456] k Exclusif: 1x [k = 2, 3, 4]	22P – Ségrégation en 2 GROUPES 2x [k = 1, 3, … , 11, 13]	5P & 10P – March. aléat. COULOIR (3min) 6x [5P, 10P, 5P]
S4	14:00	Essais Ségrégation 22P – k = 3 Décalé 2x [234, 345, 456]	22P – k = 3 Décalé (*) 4x [234, 345, 456] k Exclusif: 3x [k=2], 4x [k=3]	Ségrégation 2 GROUPES 3x [k = 1, 3, … , 11, 13] k Exclusif (**): 1x [k=2, 3]	22P – Marche aléatoire 3x [Couloir, Cylindre] (3min) + callibration
S5	15:00	(suite S4) 22P – k Exclusif 2x [k=2, 3], 3x [k=4, 5]	k Décalé : 1x [234, 345, 456] 22P – Marche aléatoire 4x [Couloir, Cylindre] (3min)	22P – Ségrégation en 2 GROUPES 4x [k = 1, 3, … , 11, 13]	22P – Ségrégation en 2 GROUPES 4x [k = 1, 3, … , 11, 13]
S6	16:00	Marche aléatoire 1P & 2P (3R) 6b, 2c, 3abc (3min)	Marche aléatoire 1P & 2P (3R) 6ac, 7abc (3min) (6b: mardi S6)	22P – k Exclusif 3x [k=2, 3], 2x [k=4]	k Exclusif en 2 GROUPES 4x [k=2], 5x [k=3], 1x [k=4]
S7	17:00	Marche aléatoire 1P & 2P – COULOIR 1abc, 2ab, y'a pas 2c (3min)	Marche aléatoire 1P & 2P COULOIR, + 1x[5P] 3abc, 4ab, y'a pas 4c (3min)	Marche aléatoire (3min) 1P & 2P (3R) - 10abc + 1&2P COULOIR 5abc	Marche aléatoire 1P & 2P – COULOIR 6abc, 7abc (3min)
Fin	18:00	(*) + d'autres à k normal	(**) k Exclusif en 2 groupes!	WIKI COULOIR	Démontage

Schedule of the second series of experiments carried out in June 2016

Thus, classical segregation was extended to the case where k = 13, and more replicas were produced for the previous values of k. One of the new experimental conditions ( ) consisted in asking the participants to segregate specifically in two clearly defined groups. Note that this doesn't mean that the two groups are homogeneous, something that participants cannot control (they only have the acoustic information of the sensors). This was carried out for k = 1, 3, 5, 7, 9, 11 and 13 (at least 20 replicas).

We also extended the criteria defining the “environment” with respect to which groups of neighbors are defined:

- the “k exclusif” criterion ( ), where *everyone* of the first k neighbors must be of the same color than the subject to stop the acoustic signal (we used k = 1, 2, 3 and 4),
- the “k décalé” criterion ( ), where the criterion of majority is used but in an environment

defined by the 2nd, 3rd and 4th neighbors, instead of the first *k* neighbors (we used 234, 345 and 456),
- and a mixed criterion, “segregation in two groups” with the “*k* exclusif” criterion ( ).

A second set of sessions were specifically devoted to the characterization of human walk.

Before the analysis of the first data set, we expected to be able to design a single mathematical model that would reproduce these segregation phenomena. However, data analysis revealed that a much more specific study must be done to characterize human walk in these confined conditions.

For this reason, we decided to implement an extra Work package WP3b.

See the description in the next WP.

WP3b: Characterization of human walk in groups confined in circular arenas

NEW: *The first series of experiments of human segregation (WP3) revealed the need for a specific study of human walk in different environmental conditions: solitary walk (in arenas of three different sizes), walking with another pedestrian (in the three arenas), and walking in groups of different size (5, 10 and 22 pedestrians) in a large arena, with and without an inner obstacle (a solid and opaque cylinder of considerable height and the small arena).*

The analysis of the data sets collected in the first series of experiments in Sept2015 revealed substantial differences from what we expected to find in the characterization of human walk from the statistical physics viewpoint. In particular, the probability density function of velocity was not a Gaussian distribution, but instead as if pedestrians would have a kind of velocity of comfort.

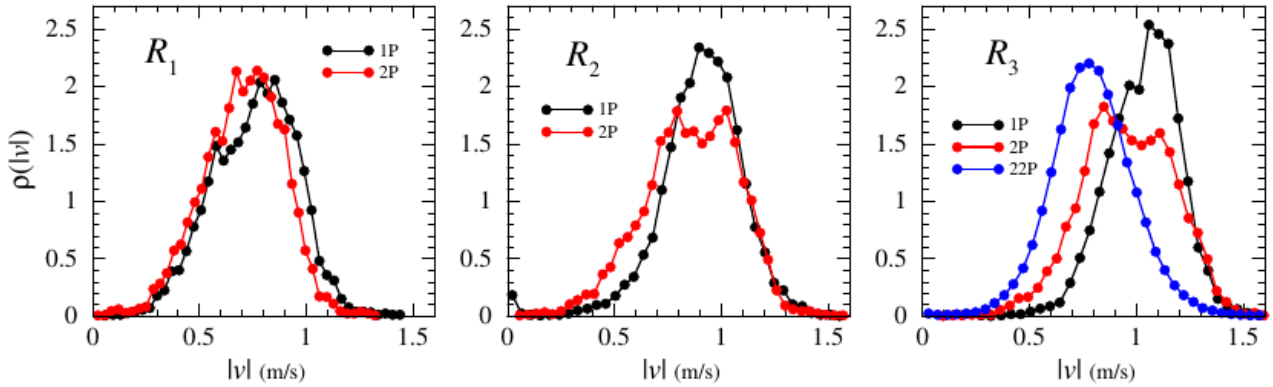


Fig. Probability density functions of the velocity in the three arenas we used (radius R_1 = 1.78m, R_2=2.52m and R_3=3.56m), for 1P= one pedestrian, 2P=two pedestrians, and 22P=22 pedestrians.

This naturally suggested us the need for a specific study of human walk, and therefore the need for larger data sets. We thus duplicated the experimental time devoted to what we called “random walk” (shown in all the blue boxes in the schedule), with series of 3 minutes with one pedestrians and 2 pedestrians in the three arenas sizes, series of 3 minutes with 5, 10 and 22 pedestrians in the largest arena R_3, and series with 5, 10 and 22 pedestrians in R_3 but with obstacles in the center of the arena. Two kinds of obstacles were used: 1) a solid and opaque cylinder of radius 1.5 m and 2m high (*i.e.*, a “hard” wall) , and 2) the small arena R_1, delimited in the floor by a colored ribbon, that subjects were asked not to penetrate (“soft” wall).

Fig. 10 subjects in the large arena

The experimental protocol is identical to the one of the human segregation WP3.

Fig. Two types of obstacles: a solid opaque cylinder (left) and the inner small arena (right)

WP4: Collective search for information

NEW: *We study how mimetic behaviors, various information sources, and past experience affect the decisions of subjects playing a game of search of information in a grid of NxN cells. Individuals are asked to find the cell with the highest absolute quality. Each individual is sensitive to only one of the M specific qualities of a product (one component of a numerical value) and don't have access to the other qualities. There are at most M types of individuals. Sequentially or in parallel, subjects have to visit a fixed number of cells in each turn and provide an information ("pheromones") about the cell. This information is visible to other subjects, and should help them to find the best cell. Subjects are rewarded by both their individual performance and the performance of the group. As subjects play the game, we expect to observe the emergence of collective searching strategies that would be more efficient than the simple addition of the individual strategy of simply using the information collected by oneself.*

As happened for WP2, the idea of the game is borrowed from the natural information exchange process used by insects (especially ants): the pheromones. In WP2, pedestrians leave a kind of pheromone at each bifurcation, which is the number of times a corridor has been employed. In the present case, the "pheromone" is the information that subject provides about the quality of the cell they are sensible to. In both cases, subsequent subjects can make use of their personal information and an external information provided by the others (social information) to make their decision.

In the case of the corridor bifurcation choice, the remanence of information (an essential property of the pheromone mechanism of information transmission) consisted of putting a limit to the time interval about which the information was provided. That is, the information shown at each corridor bifurcation referred only to a short period of time (typically the previous 1-2 minutes). In the case of the searching game, the pheromone mechanism can be implemented with a higher fidelity, making the social information to literally evaporate from one turn to another.

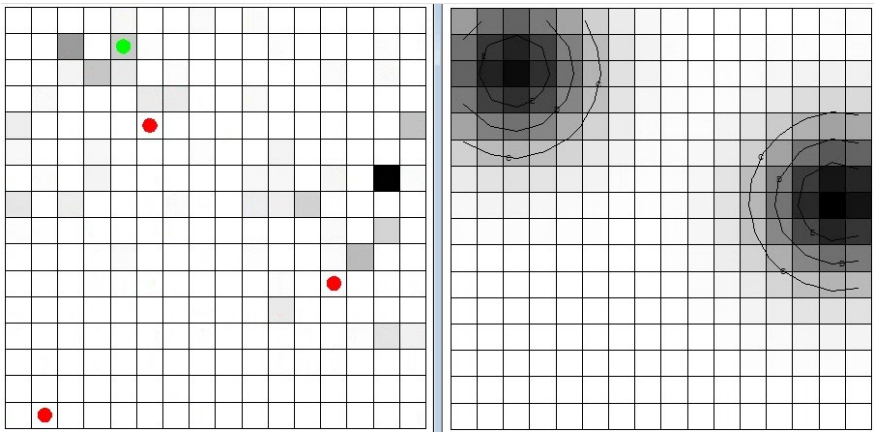


Fig. First version of the artificial intelligence code in a grid of size 16x16 with two maxima. Left: current state of the collective searching strategy. Right: location of maxima.

A first version of the game has been implemented in Yorick (an interpreted programming language for scientific simulations or calculations) with the simulation of the artificial intelligence of N players in a grid of 20x20, 50x50 and 100x100 cells). The left panel in the previous figure shows the current state of a collective search of the two maxima shown in the right panel. Both locations have been more or less identified (darkest cells). Other cells are still being visited, but they soon lose darkness intensity due to the effect of evaporation.

A second version has been implemented in Fortran (a general-purpose programming language especially suited to numeric computation and scientific computing –Wikipedia-en), where a game environment in a tactile screen has been added to the artificial intelligence, allowing the possibility of playing with *N*–1 simulated players. The game has later been implemented to play in a network of 10-20 computers in a computational platform which would allow the possibility of combining online gaming with smartphones and tablets.

The experimental protocol is described in a slide presentation. A brief overview is shown in the next figure, which describes the turn of one player. From left to right and top to bottom: the player is faced with a grid with already some social information (intensity of red); he then choose a cell (according to his individual strategy, based on the information he collected in the past –previous turns– and the pheromone field). A number is revealed, corresponding to the value of the quality this specific player is sensible to. The player is then asked to evaluate the cell (here with 0, 1, 2 o 3 points or units), and is informed about the individual performance of this turn.

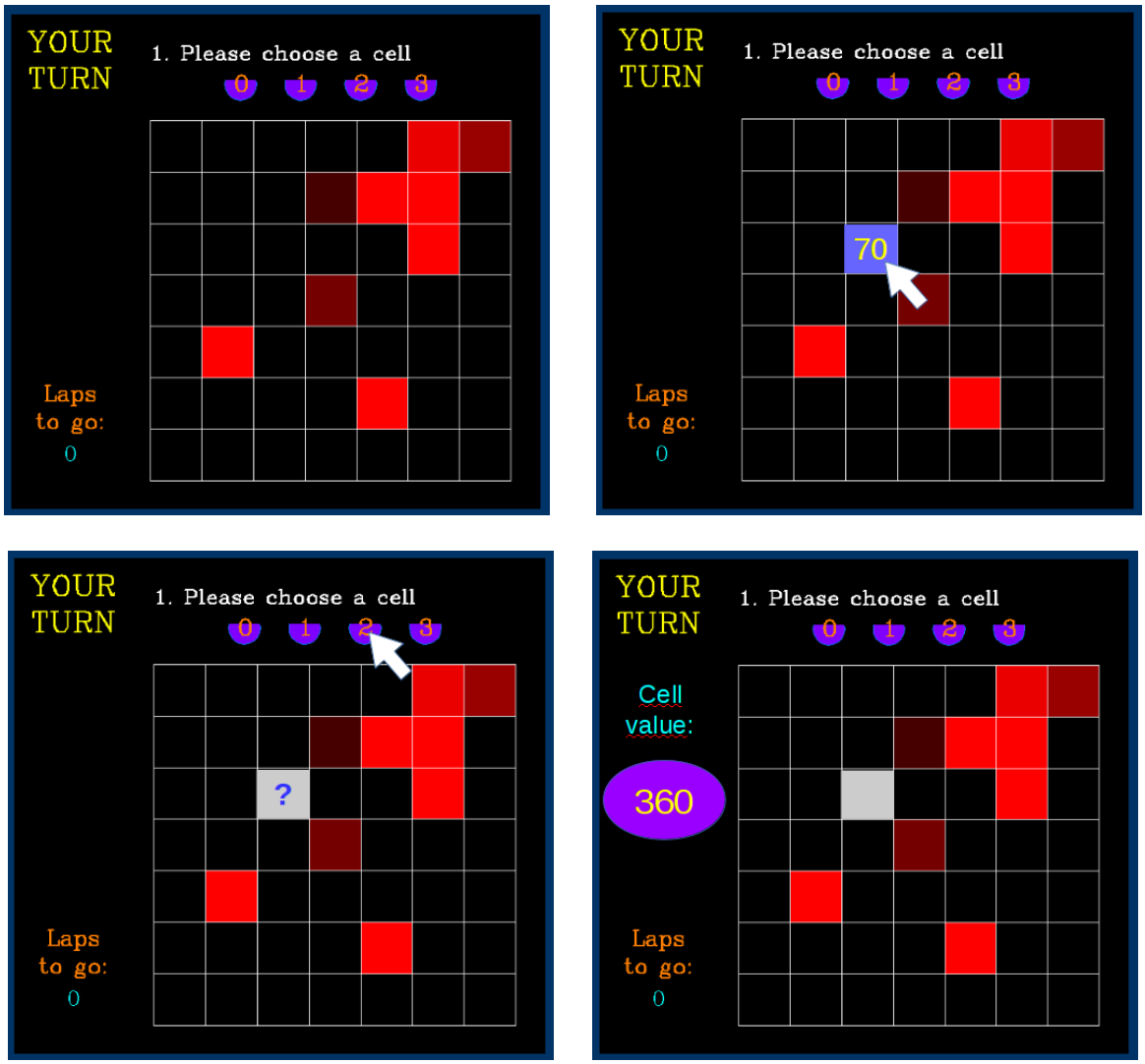


Fig. Successive panels the player is confronted to during a turn in the search of information game.

The experiments are already planned to be carried out during the next three days 03–05 May 2017 at Toulouse School of Economics (TSE), the same place as WP1.

4. Comments (Version January 2016)

1• Working group meetings are rising up a fabulous number of questions around the main topic under analysis in this project, namely, *the promotion of (emergence of) human collective intelligence*. Our attention recursively focuses on the following situations: the cultural bias (including the personality of participants) in the experiment of collective estimation, the possibility to push the participants to complete segregation (that is, in two distinct groups that are visually separated by a straight line), and a new situation in which individuals have to share some private information to enhance their performance at the collective level (see below).

2• As already mentioned, we are planning to carry out the same experiment in Bilbao, to see the effects of Spanish culture with respect to the French and Japanese cases. A second series of segregation experiments is being prepared for the last week of April, in which a new instruction will be given to the pedestrians, which is “your goal is to be divided in two visually distinct groups”.

3• Finally, we are also planning to carry out a new series of experiments, in the same experimental conditions than WP1, that is, a room with 10 isolated work-stations. The experiment will consist on a game played by the 10 participants on a board of NxN cells (the value of N is linked to the value of other parameters, in particular the time of resolution of the game, and will be determined after a preliminary analysis of the game which includes numerical simulations).

The problem consists in finding the cell(s) with the maximum value of a product, max(V). Players don’t know the function $V(x,y)$ and will have to explore the field according to some rules. They will have access to some partial information –partial both spatially and qualitatively– that they will have to share (but they can eventually decide not to share the information they obtain individually).

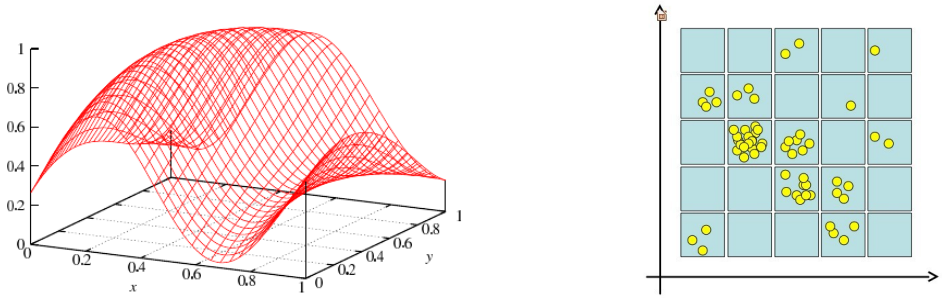


Fig. 13. Left: Example of function $V(x,y)$, and Right: of pheromone field, after some participants have left some units of information (pheromones).

Our idea is to analyze this problem by means of a sequential game. In each round, a player is able to explore a limited number of cells. Each player is sensitive to only one of the three characteristics of the product (*e.g.*, color, form and weight), so that the information the player collects is partial. Then, the player decides to what extend he wants to share this information with the other players.

The mechanism of information transfer is what introduces the collective component of the model: players have access to 1) the information of the characteristic of the product they are sensitive to, and 2) the information provided by previous players. We expect that the objective will be found by the group by combining the specific individual knowledge that each kind of player can obtain about the components of the product with the qualitative information they build collectively.

5. Comments revised (March 2017)

1• We have extended WP1 to another series of experiments carried out by our collaborators in this study in Japan, and a new series of experiments will be/have been carried out in Toulouse (TSE, as previous ones) in April 2017, with different experimental conditions. The main interest of this new series of experiments consists in the introduction of a variable level of accuracy in the information provided by the experts during the successive estimates that participants have to formulate. This is extended in the experimental protocol of WP1.

2• In turn, experiments of WP1 planned for Bilbao have been left for a posterior date.

3• The idea of the “game” sketched in the previous comment has been developed as a whole Work package WP4, “Collective search of information”, based on similar concepts than WP2. We have designed a computational platform to “play” the game. This new WP is at the pre-experimental stage.