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# Assessment of ICT Contribution to the Learning Process

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***Abstract-*** This study undertaken in both naturalistic and experimental conditions aimed at assessing objectively the use of ICT by students whilst attending an academic lecture and to gauge the disturbance effect of ICT use on the learning process. Observations were carried out from end 2012 to end 2014 in a UK university (*N*=596, MSc, Human Sc. discipline) distributed in 11 sessions in order to objectify the level of students' ICT use. Then an experiment was carried out in laboratory with a sample of these students (*N*=40) to assess the disturbance of ICT on learning process depending on frequency of use of ICT and their nature (class related or not), dividing the sample in 3 groups: control group1 (not disturbed), group 2 (disturbed by web class related resource) and group 3 (distracted by exchanging messages on mobile phone). Groups 2 and 3 were distracted at a controlled frequency equal to 30 occ/h. Performance assessment in 19 points was based on the revised Bloom's taxonomy complemented by an ontology-based assessment technique. We found out that 63% of students used ICT during academic lectures and that groups 1 and 2 had similar performance while group 3 significantly had poorer performance ($p<.001$). Results were explained in the light of the Information Processing theory and Mayer and Moreno's model developed for multimedia learning. These results identified a threshold for ICT use and warned teachers (resp. students) about an abusive use of ICT to support lessons (resp. about non-class related use of ICT).

***Keywords-*** *computer-mediated communication, improving classroom teaching, media in education*

## I. INTRODUCTION

Information and Communication Technologies (ICT) are increasing in importance every day, especially since the 90's (last decade of birth for the Millennials generation, born between 1979 and 1994; see [1]). While social interactions involving the Millennials generation have been studied, very few investigations are available regarding the use of the ICT by this generation as well as the impact on outcomes in education and professional training.

In terms of expectations, a 2012 report from Educause Center for Applied Research [2] involving about *N*=10,000 students from USA-based institutions showed that students' whishes for teachers' technology usage had doubled from 2011 to 2012 especially for open educational resources and serious games. In addition, 85% said laptop was very/extremely important to academic success, and students' preference for communication was face-to-face interaction immediately followed by email and text/instant messaging. In 2008, Fried [3] carried out a study in USA with *N*=137 students of General Psychology among whom 64.3% reported using their laptops in at least one class period, multitasking (email: 81%, instant messaging: 68%, surfing the net: 43%, playing games: 25%, other: 35%).

Observing and interviewing students preparing a MSc at the London School of Economics and Political Science (LSE students) between in 2012 and 2013, we aimed in a previous study at characterizing the students-ICT interaction during the courses [4-5]. Direct observations were necessary as students are used to underreporting the frequency of their in-class use of ICT when answering questionnaires [6]. We found that up to 50% of the students (mainly female) among *N*=180 could use ICT during courses at a rate of 0.84 occurrence/minutes (about 50 occ/h) for some of them, and they thought this involvement did not distract learning, even was helpful. They usually perceive that digital devices have positive impacts on their academic success [7]. The LSE students' use of ICT could be class-related (academic web resource) or not (personal email, sms, social network). Yet in 2013, researches undertaken with about *N*=300 students showed that multitasking led them think they are much better than they actually are [8], findings consistent with earlier studies [9]; it suggests students cannot multitask as effectively as they think they can. However, Strayer et al. [10], investigating a connected issue related to the use of cell-phones by motor-vehicle drivers (*N*=40), found out that "although the vast majority of individuals cannot perform this dual-task combination without impairment, a small group of 'supertaskers' can" (p. 29).

In parallel, several studies have shown the negative effect of ICT use during classroom on the global academic results (see for example [3, 6]), but conversely, recent longitudinal studies [2, 11] pointed out a positive effect of ICT on global academic assessment. However all these assessments were based on self-reporting of ICT use by the students, which are biased as said above. Other one-off recent studies in learning context have led to similar opposed conclusions. North American students attending a PowerPoint lecture disturbed meanwhile by online tasks had a knowledge assessment

afterwards through a test of 20 questions. Sana et al. [12] concluded to a negative effect of online tasks on acquiring knowledge from the lecture, whereas Li et al. [13] differentiated a negative effect on recalling but positive effect on encoding.

The question of whether use of ICT contributes positively or negatively to the learning process in academic context seems therefore not resolved. This relates to multitasking: the main task (attending the lesson to learn) is disturbed by a secondary or distracting task or distractor (using ICT). This notion of distraction is actual only when the use of ITC is effectively a secondary task, and not integrated in the learning process as it is the case with integrated environmental learning [14] or web-based blended courses adopting online learning, mobile technologies and other ICT resources [11].

Investigating the question in a fully controlled context implies controlling especially the content of online tasks, their duration and their frequency. Very few studies are available regarding this particular question. Even, as we shall see further, these suffer from some weaknesses or confusions (or even combine them all) regarding especially the distractor type (pertaining to the secondary task), the emotional characteristic of the distractor, and the distractor frequency.

The present study aimed at producing a strictly quantified assessment of ICT contribution to the learning process in academic context, and at suggesting a theoretical depiction of the findings.

## II. METHOD

The study was made up of two parts: a collective observation and an experiment.

### A. Design of the collective observation

The collective observation (first part) was made up of additional observations in naturalistic conditions during academic lectures in order to consolidate the previous results [4-5] regarding the general use of ICT by students. Here, ICT were understood under five designs: the mobile phone, the smartphone, the tablet, the netbook and the laptop. The conditions of collective observation were similar to the previous study: observations were made during a weekly two-hour lecture in social psychology for MSc, each observation lasting one hour, at the balcony level of a theatre, far from the lecturer standing on the stage. The lectures did not require any access to internet or any special use of ICT; this means that ICT could be used according to students' needs, mainly to write down notes about the lecture and for other purpose as well. The position of observation was chosen in order to watch the students' natural behavior [4].

### B. Design of the experiment

The design of the experiment (second part) was motivated by the desire to compare learning performance obtained after different distraction conditions in class. Subjects were involved in a main task (attending a lecture to learn) and periodically distracted by a secondary task. Controlled parameters were: the nature and duration of the main task, type, nature and frequency of the distractor (secondary task), profile of students attending the lecture. We present hereafter how each of them was designed.

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*Main task*. Students were attending a 13 minute video-recorded lecture (lecturer presenting PowerPoint slides) at the Behavior Research Laboratory (BRL) of the LSE. Each student had to come with their own ICT (a mobile phone, a smartphone, a netbook, a laptop or tablet with Wi-Fi), pen and notebook, as if they were going to a daily course. The lecture was about an unknown topic (related to Physic Science) for the students (Human Science).

*Type and nature of distractors*. Two types of distractors were used. One was class-related type. These distractors were web links which had to be consulted by the subjects. We blinks were related to the taught topic as a learning resource, and their content had been prepared by the lecturer. The lecturer asked attendees to open them regularly during the lecture. These web contents provided the subjects redundant information with the lecture (for 80% of the web links) and/or complementary information (40%). Redundant information aimed at improving encoding of information and complementary information aimed at giving additional possible answers during the assessment.

The other type of distractors was based on the use of mobile phone to exchange messages (sms); these distractors were not class-related. Relying on other researches showing that the valence of the emotional content (negative, positive, neutral) of a cognitive secondary task affected differentially the performance of a main task [15-19], the distractors were made as neutral as possible from the emotional standpoint. This choice was done in order to produce a distraction as similar as possible from one subject to another. This choice had another consequence: reducing the impact of the distraction by avoiding the emotional contribution, we could postulate that our experimental condition would give the lowest effect possible regarding the distraction. In other words, we could consider that any other naturalistic situation of learning distracted by message exchanging would give poorer performance. Therefore these were basic sms such as: Where are you? How is the weather? These sms were prepared before the experiment. Full list is given in appendix.

We verified that the overall potential time spent regarding the secondary tasks was in agreement with previous results obtained by Kraushaar and Novak [20] and applied by Sana et al. [12] suggesting that this would not exceed 40% of class-time.

*Frequency of distractors*. The frequency of the distractor was set up from the results of the very few studies available in the literature. Indeed, there is a profusion of papers regarding distraction during basic cognitive processes (main task lasting a few minutes and distractions lasting a few milliseconds) such as learning/recognizing/recalling words (see for example [21-24]), learning/recognizing/recalling pictures (see for example [24]), learning/recognizing/recalling patterns (see for example [25-26]), but few studies tackle the effect of distractions of several minutes during a lengthy cognitive task such as attending a lecture. Another research domain investigates distractions during long lasting cognitive task but this concerns drivers in distracted conditions due to the use of mobile phone (see for example [10, 27-31]). In these conditions, the learning process is not concerned and the findings and conclusions cannot be applied to our research topic.

As we aimed at controlling the frequency of distractions, we could not take benefits of neither studies analyzing the students' ICT use based on their own need [13, 32] (Hembrooke & Gay, 2003; Li et al., 2010), nor studies based on a students' self-reported level of use [6]. The former is not useful as students' own need does not give stable and reproducible frequency; the latter is tainted by a high level of uncertainty as students underreport the frequency of their in-class use of mobile phones [6]. We may notice here that they all concluded in negative effect of ICT on learning process.

Table 1 gives an overview of conditions and conclusions regarding studies of ICT distractions during long lasting tasks for students for which distractor frequency could be known.

Similarly we could not take benefits of Ellis et al.'s studies [33] who mentioned sending 3 sms during a lecture the duration of which was not given. They also concluded in a negative effect of ICT on learning process.

Bowman et al. [34] asked students to read a five-page text on a computer screen with one distractor per page (Instant Messaging) and measured the average time for reading ($M$=45.57 min.); we thus approximated the distractor frequency at about $f$=6,6 occ/h; they concluded that there was no significant ICT effect. Sana et al. [12] presented a 45min. PowerPoint lecture with 12 non-lecture-related online tasks as distractors; this led to the calculation of $f$=16 occ/h; they concluded in an ICT negative effect. Rosen et al. [44] produced a 30 min. recorded lecture for the students distributed in 3 groups and sent 0 or 4 or 8 text messages meanwhile; as some students did not received some messages and others were texting additional sms, they analyzed data distinguishing 3 categories: not texting, texting at $f$=16 to 32 occ/h, texting at more than $f$=32 occ/h; for the former they concluded in no effect and for the latter they concluded in an ICT negative effect.

Wood et al. [35] (2011) made students attending a 20 min. recorded lecture and suggested them to multitask as they wanted such as texting, sending email or msn, browsing on Facebook; frequency of the secondary task could be approximated to $f$=30 occ/h; they concluded in an ICT negative effect.

TABLE 1 CONDITIONS AND CONCLUSIONS REGARDING ICT DISTRACTIONS DURING LONG LASTING TASKS FOR STUDENTS.

| Author(s) | distraction effects (*) | participants' characteristics | number of participants | | | main activity | | distractors | |
|---|---|---|---|---|---|---|---|---|---|
| | | | total | control group(**) | distracted group | type | duration | type | frequency |
| Bowman et al. (2010) | none | college students in psychology | 89 | about 30 | about 2 x 30 | reading text about psychology on computer screen | about 45 min | texting | about 6,6 occ/h |
| Sana et al. (2013) | negative | undergrad. students in psychology | 40 | 20 | 20 | powerpoint lecture in meteorology | 45 min | laptop | 12 online tasks (about 16 occ/h) |
| Rosen et al. (2011) | 1)none 2)negative | undergrad. students in psychology | 185 | none | 44 + 76 + 65 | recorded lecture | 30 min | texting | 1)16 to 32 occ/h 2)over 32 occ/h |
| Wood et al. (2011) | 1)none 2)negative 3)negative 4)very negative | university students | 145 | about 3 x 20 | about 3 x 20 | lecture on research methods | 20 min | 1)texting 2)email 3)MSN 4)Facebook | continuous (likely about 30 occ/h) |
| Froese et al. (2012) | negative | college students in literature | 80 | 80 | 80 | powerpoint lecture about a new book | 6 min | texting | continuous (likely about 30 occ/h) |
| Kuznekoff & Titsworth (2013) | 1)negative 2)negative | university students in comm-unication | 47 | 19 | 2 x 14 | recorded lecture | 12 min | IM+facebook | 1)60 occ/h 2)120 occ/h |
| Pashler et al. (2013) | negative | undergrad. students | 109 | 109 | 109 | reading | about 7.5min. (excluding distraction time) | opinion questions | about 72 occ/h |

(*) distraction effects on learning for distracted groups vs control group
(**) "control group" means no distraction.

Froese et al. [36] produced a 12 min. recorded lecture for students texting continuously, leading to approximately f=30 occ/h according to the details given by the authors; they concluded in an ICT negative effect. Kuznekoff and Titsworth [37] made students attending a 12 min. recorded lecture and sent every 60 s. simulated sms for what they named the "high-distraction group" and every 30 s. for what they named the "low-distraction group", leading to $f$=60 and 120 occ/h; they concluded in an ICT negative effect. Palshner et al. [38] presented a 7.5 min. PowerPoint lecture to students answering opinion questions at about $f$=72 occ/h; they concluded in an ICT negative effect.

These seven studies assessed students' performance regarding the integration of the lecture through post-test ranging from 10 to 25 questions, taught topic being previously unknown from the students, most of the time through multiple choice tests.

Considering this data dealing with texting-based secondary task (therefore not considering Sana et al.'s work [12]), one threshold appeared at about $f$=30 occ/h, over which ICT had a systematically negative effect, under which ICT use seemed mainly to have no effect on learning process. Hence the frequency of distraction in the present experiment was chosen at $f$=30 occ/h. Some subjects were submitted to sms processing at this frequency, and other subjects had to consult weblinks (see § "Procedure").

*D. Subjects*

Regarding the collective observation, no selection was done. Students came attending the lecture in social psychology and observations were done respecting strictly anonymity as the observations were just resulting in counts of attendees. They were MSc students in Psychology. The total of students observed was $N$=596 distributed over 11 sessions between end 2012 to end 2014.

Regarding the experiment, the selection of the subjects was processed by the administrator of the BRL via an internet portal according to the criteria given by the researcher online. Participants were expected to be in first or second year MSc at the LSE (Human Science program), less than 35 years old. in order to represent to generation of students concerned by the use of ICT, the Millenial generation according to Myers & Sadaghiani [1]. Students engaged in Economics or Statistics courses were refused because they could have been given information related to the taught topic in a far past. Students had to be English native language or to have a TOEFL score greater than 107/120 in order to avoid a bias due to comprehension (all foreign students of the LSE are required a 107 score at least). Students were granted of £10 for retribution of their participation. Each student agreed and signed the conditions of the consent form regarding the experiment, the ethics application of which was approved by the Ethics Committee of the Dept. of Social Psychology of the LSE and by the BRL. The total of students participating was $N$=40.

*E. Apparatus*

Regarding the collective observation, no specific equipment was used.

Regarding the experiment, students were welcomed in a room of the BRL where each one sat in individual cubicle at a desk with PC screen, keyboard and mouse during 1h. This configuration reduced any influence of the group on individual, reduced the number of external stimuli that could distract the subject and therefore allowed researchers to control distracting stimuli, and likely reinforce the subjects' implication as isolated in a cubible and watching the video alone. Students concerned by sms processing used their own mobile phone. Those concerned by web links consultation could do it with their own computer as the lab was equipped with Wi-Fi, or with the connected computer at their disposal.

The sms were sent altogether at the same time to all mobile phones. This was performed from the researcher's computer through the online service of the French operator Orange allowing clients to manage such type of sending. Prior tests were undertaken to assess the reliability of sms sending. The delay between sending and receiving for a series of ten trials presented a standard deviation of 3.8%, meaning that we could consider that the subjects received sms quite at the same time. When sent at a period of 2 min. ($f$=30 occ/h), the mean period differed from the expected value less than 0.7% with a standard deviation less than 5%. The frequency was therefore quite reliable.

The web links were consulted by the students according to the lecturer presentation through the video recording. The lecture was recorded to be sure that web links would be asked to be consulted in due time. Nevertheless, suggesting web links in relevant coherence with the content of the presentation did not allow an accurate conformity to the chosen frequency for which the mean value was 2 min. and 32 s.

Just before undertaking the experiment, the reliability of Wi-Fi connection in the BRL was verified, and each computer was tested to be sure of the audio-video quality.

*F. Procedure*

Regarding the collective observation, the procedure was quite simple: attending the lectures in the theatre, waiting for the beginning of the lecture and for all students to be in the theatre, and observing for 1 h. after about 10 min. for students to have effectively settled themselves. The total number of students in the theatre was counted; the number of students using ICT was counted and their gender was noted. Using ICT was defined as having a tablet, netbook, laptop or a phone on the table or in hands, whatever the duration, and at least having one interaction with it.

Regarding the experiment, students were received in the BRL, were assigned randomly to a condition and then were placed in a cubicle. They were presented the aim of the experiment, had to read and sign (if agreement) the informed consent. Students were updated that performance assessment would be taken at the end of the lecture and that the answers for would be available online after the experiment.

The random assignment divided the students in three groups.

Group 1 (group control, $N$=12) had to listen to the lecture, taking notes on paper, laptop or tablet as they wanted, not

allowed to use mobile phone (switched off) and not allowed to use websites.

Group 2 (web, *N*=14) had to listen to the lecture, taking notes on paper, laptop or tablet as they wanted, and not allowed to use mobile phone (switched off). They were asked (mandatory) to use through their ICT a web link related to the taught topic as a learning resource. This yielded 5 web connections during the lecture.

Group 3 (sms, *N*=14) had to listen to the lecture, taking notes on paper, laptop or tablet as they wanted, had to keep the mobile phone switched on, and not allowed to use websites. They had (mandatory) to answer 6 sms (neutral from cognitive and emotional standpoints) sent to them regularly. These students had to communicate before the experiment their mobile phone number in order to receive sms. They had to reply to each sms, sending an answer to the researcher's mobile phone. This allowed the researcher to control that they had effectively processed the sms.

The distribution of the subjects per groups gave rise to preliminary statistical calculations in order to verify that a t-test of Student regarding the comparison of the mean performance per group could be relevant. Combined to a pilot study, we found that the statistical power would be greater than 0.8.

Immediately after watching the lecture, subjects were given the assessment form made up of two parts: a knowledge assessment and a fidelity assessment.

The performance or knowledge assessment was based on the revised Bloom's taxonomy [39, 40] using adapted level of assessment of the taxonomy according to the context. This was complemented by an Ontology-based assessment technique (list of words or expressions, related to a same main topic, to be organized according to a hierarchically structured set of terms for describing a domain; see [41, 42]). Both recalling and encoding were concerned. The performance score was calculated as a success rate to the 15 criteria assessed by 19 points. The use of written notes or any ICT during the assessment was forbidden. A pre-test assessment of knowledge was not necessary as the students did not know the topic before.

The fidelity assessment was applied too. As done by Wood et al. [35], the fidelity questionnaire was used to characterize the compliance (what profile they had, whether or not they knew about the taught topic before the lecture, whether or not they adhered to instructions), the amount of secondary tasks and their nature (if students had used devices, how many times, due to which reason), the technology use (whether or not students had used the required devices).

## III. Results

### A. Results of the collective observation

The collective observation distributed over 11 sessions in naturalistic conditions during academic lectures showed that students (*N*=596, 85% female) had an increasing tendency to use ICT during lectures over the period of observation. Figure 1 shows that the trend was increasing towards a value oscillating around a mean value equal to 63%. In parallel, the ratio the involvement of students in ICT use per gender showed that female used more ICT than male at the beginning of the period of observation, but that it came to a stable value around one, illustrating now an equal use of ICT by female students as by male students. During the observations, most of the students using ICT had their device on the table or on the knees or in hand during the whole hour.

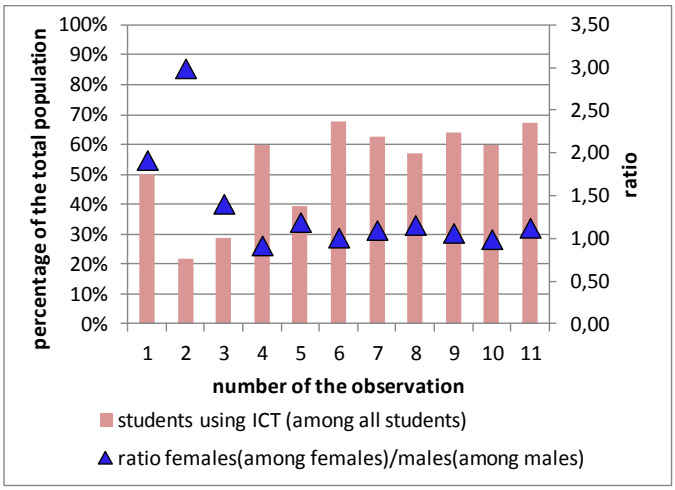


Figure 1. Percentage of students using ICT (among all) and ratio of the percentage of female students (among female) over percentage of male students (among male).

### B. Results of the experiment

Headings the number of participants per group was lowered compared to the 40 expected; 13 were not considered:

- 1 subject did not come,
- 4 did not comply strictly to instructions (e.g. replied to extra sms (higher frequency and no control on the emotional content) or connected on line while forbidden),
- 4 did not matched the required academic training,
- 1 did not filled the sociodemographic data,
- 2 were eliminated because out of the age range considered,
- 1 was eliminated because knew partly the subject before taking the test.

This means that about 32% of the cases could not be used. This rather high level of not acceptable subjects is assumed to be partly due to the way participants registered online at the BRL and how information was available: participants read one box and not the additional information. It means that the research team must write all requirements in one box. These difficulties were combined with the fact that no control was possible before the day of the experiment, according to what explained the BRL administrator, due to anonymity concerns. Thus, it was just when participants were fulfilling the sociodemographic questionnaire that selection could be done, but this was however too late to summon other participants.

There remained *N*=27 subjects included 22% male students and the average age was 23.1 years old for the whole sample.

The results obtained are summarized in Table 2. Significance of the differentiation of the mean values was assessed through a t-test of Student.

TABLE I. RESULTS OF PERFORMANCE ASSESSMENT

| **Group** | group 1 (control) | group 2 (web) | group 3 (sms) |
|---|---|---|---|
| **Number of subjects *N*** | 10 | 9 | 8 |
| **Mean performance score *X*** | 70.0% | 69.0% | 60.5% |
| **Relative performance change compared to control group (*)** | 0% | -1.4% | -13.5% |
| **Variance of performance $\sigma$** | 0.02 | 0.04 | 0.02 |
| **Comparative analysis** | group1/ group 3 | group 1/ group 2 | group 2/ group 3 |
| **t-test Student: *t*** | 8.42 | 0.67 | 5.13 |
| **$t_{critic}$ (*p*<.001)** | 4.01 | 3.96 | 4.07 |

(*) Example of calculation: for group 2, the relative performance is (69-70)/70= -1.4%

Among all the qualified subjects for the analysis, only two of them had the maximum performance score, one within group 1 (control group) and one within group 2 (web resource).

The right answers for the assessment questionnaire where not given in place but put online a few hours later. Subjects were updated about this detail at the beginning of the experiment. Some of the students thought this would be done however in place after the test and while leaving the lab, they asked confirmation about this to be online soon. Other students left the place thanking the researcher for the interesting lecture. These behaviors illustrated their motivation to answer correctly the questionnaire.

Statistical power calculations showed that when mean values have significant difference applying t-test of Student, the test power was greater than 0.8 which confirms the consistency of the data.

## IV. DISCUSSION

### A. Collective observation

Students using ICT during lectures showed a proportion oscillating around 60% with an equal use for female and male students. One could object that this value depends on the number of owners of ICT among the sample but a survey undertaken in 2013 by the Center of Learning and Teaching of the LSE among 1070 students showed that 99% of them owned a laptop and a mobile phone among which phones only 8% did not have internet access and that almost all students attended lessons with their phone and half of them with their laptop [43]. This result suggests that the number of owners of ICT among the sample of the present study may be considered equal to 100%: the correction that applied to the percentage calculated in the present study is negligible. Furthermore, as the results are obtained through direct observations, they are not tainted of the inaccuracy due to self-reporting of students' use. It would have been interesting to compare them with other studies, but ours appear to be a first published in the literature.

Hence, our results reflect the importance of ICT at the university with an objective approach and are close to subjective results obtained elsewhere (68% for Duncan et al. [6] with US astronomy students): while lecture did not require any access to internet or any special use of ICT (only according to students' needs and mainly to write down notes about the lecture) more than one student over two use them during the lecture and there is no differentiation with the gender. As mentioned in the previous study [3-4], the use of ICT may be for learning purpose or for personal purpose.

### B. Experiment

*Distractor frequency as a performance threshold*. The distraction by sms (non-class-related distraction, group 3) at a frequency of 30 occ/h did significantly change the performance of the students in agreement with what was expected from the results available in the literature and presented in Table 1. The t-test values calculated for the comparison between this group and the two other groups were significant with p<.001.

This leads to a remark regarding Kuznekoff & Titsworth's experiments [37] who carried out experiments with distractor frequencies equal to 60 and 120occ/h and who named former condition "low frequency" and the latter "high frequency". According to the present results and to results of studies in Table 1, we suggest that these conditions should be named "high frequency" and "very high frequency" resp. Furthermore, they could differentiate these two conditions in terms of performance. This contributes to show that, for texting-based secondary task, higher distractor frequency than 30 occ/h produces a negative effect on the learning process. On the contrary, when decreasing the frequency, this negative effect may disappear as proved by Bowman et al.'s experiments [34]. As these researchers did not seek neutral emotional valence of texting, we may assume that the equivalent distractor frequency with neutral emotional valence of texting would produce a lower distraction effect and consequently a better learning performance. Therefore this suggests that if a threshold zone is sought about which the effect of distraction switches from positive to negative effect on the learning process, the interval to investigate must cover a range of frequency from 6.6 occ/h to 30 occ/h.

*Class-related distractor improvement*. The distraction by class-related distraction (web, group 2) at a frequency of 30 occ/h did not change the global performance of the students compared to the control group 1. The maximum individual performance score was obtained within control group 1 and group 2 (web). However, these results show that if the web resource is used with the objective to enhance the learning process during lectures, it seems that this must to be done at a frequency lower than 30 occ/h. In other words, if teachers want students to take benefits of online resource during their academic lectures, they must do their best to structure their suggestions of online resource consultation at a frequency lower than 30 occ/h.

Yet, regarding the present results compared with those of the studies presented in Table 1, we could expect a better performance for this class-related distraction than for the control group. Indeed, if non-class related distraction at f=30 occ/h in similar conditions to the present study gave no disturbing effect [35, 44] then for class related distraction at this frequency we could expect a positive effect. Furthermore, as discussed above, the fact that the present experiment were carried out with neutral valence of distractors AND class-related distractors could have led to a lower impact of distraction and thus to a higher performance with expectation of a positive effect on the learning process. This was not observed: the effect was "none". The explanation of such a result may be found in Hembrooke and Gay's work [32]. They made students attending a "typical" academic lecture (duration not communicated) and asked them to bring along their laptop and to use it according to their need. They assessed the performance according to three criteria: global knowledge, recall and recognition. They found out that the distraction due to laptop use produced a negative effect on the performance for the sample of subjects (*N*=88 cases). Then they refined their analysis differentiating subjects according to the content of web pages the students had viewed: some subjects were "browser" type (browsing web unrelated class pages) and others were "seeker" type (browsing web related class pages). They discovered that "the more time browsing web unrelated class pages, the higher recall score" (p. 10). They suggested that "browsers" ' attention was more available for the lecture as the subjects were less interested in the content of web pages than the "seekers". In the light of these findings, we may assume that in the present experiment, the subjects of group 2 (web) were of "seeker" type as they viewed web related class pages while in Rosen et al.'s experiment [44] and Wood et al.'s experiment [35], subjects were of "browser" type (dealing with unrelated class task). This might explain why the present experiment led to a neutral effect of web resource whereas a positive effect could be expected. Furthermore, this is consistent with functional neuroimaging showing that increasing cognitive load by dealing with a secondary task during learning modulates the degree to which subjects use declarative memory (mainly involved in this kind of learning process), not reducing accuracy but reducing the amount of declarative learning about the task [45]. In the present study, the fact that the secondary task in group 2 (web) was also a learning task likely amplified this phenomenon and overloaded declarative memory conversely to the non-class related task of group 3 (sms). Mayer and Moreno [46] suggested an interesting theoretical approach to explain the associated overloaded information process in the case of multimedia learning as it is the case for the present study. In the light of the Information Processing theory [47], Wickens and Hollands' model [48] advocates to consider a hierarchy for different cognitive functions. The schema on Figure 2 presenting the model suggests that information process starts with sensory functions before being accessed by the cognitive channel to be processed by basic cognitive functions such as attention, memory (working memory, WM, and long term memory, LTM) and reasoning, while complex cognitive processes are the combination of these basic cognitive functions.

The interaction between WM and LTM may be described interestingly by Mayer and Moreno's model [46] integrating earlier work [49] suggesting that subjects use separate memory channels for oral and visual information leading to a dual processing conception of learning. This divides WM into a visual channel and an auditory channel, independent of one another to some extent and both limited in capacity. Mayer and Moreno [46] showed that in the case of multimedia learning, the dual processing could significantly overload the cognitive process of information. This was confirmed by others (see for example [50]).

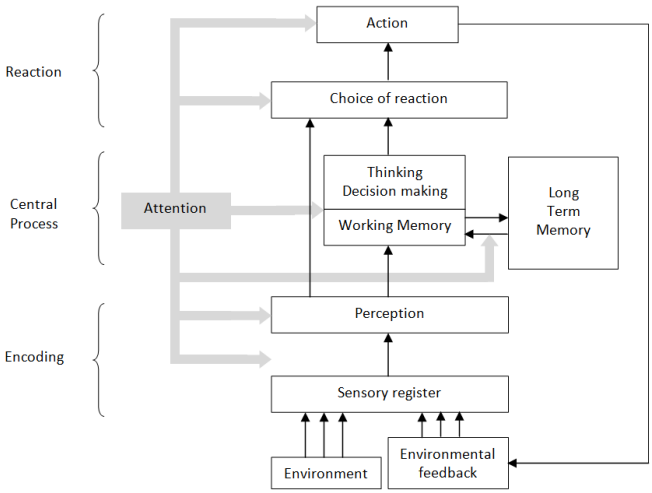


Figure 2. Information processing approach (adapted from Wickens and Hollands, 2000 [48]).

Indeed in the present experiment, subjects were precisely submitted to a periodic overload in the frame of a dual cognitive process of information, processing speech, pictures, reading words. When subjects only watched the lecture (group 1), both channels were solicited and there was likely no overload. When subjects browsed a web resource in parallel, both channels were solicited with the auditory channel overloaded compared with the aforementioned situation: the auditory channel overload was due to information provided by the lecture (not watched but heard simultaneously). Yet Mayer and Moreno [46] as well as others (for example: [51]) suggested that this phenomenon was favored by the "redundancy effect" pertaining to the necessary dual informative aspect of certain information, perceived both by the auditory channel and by the visual channel. In the present experiment, the redundancy effect happened when subjects read words written on a slide of the powerpoint lecture and heard these words said as the same time by the lecturer, or when they viewed a 40 sec. video with blank soundtrack among the suggested web resource. We may assume that the load of the dual cognitive process of information was higher for group 2 (web) than for group 3 (sms). At the same time, referring to Wickens and Hollands' model [48] on Figure 2, attention was disturbed in both distracted groups. Yet the disturbance was class related for group 2 (web) in which the subjects did not miss any information as for this group the distractor provided redundancy and/or complementary information, while for group 3 (sms) the subjects' attention was

directed to another purpose. This may explain why group 3 (sms) had poorer performance and why group 2 (web) did not improved performance compared with the control group 1.

## V. Conclusion

The findings of the present study are of great interest both for teachers and students. For teachers, it must be kept in mind that a profusion of web resource may not help students' learning during their lecture and that a frequency of 30 occ/h is a value that does not provide good conditions for learning. For the students, it must be known that non-class related distractors (in their basic form, i.e. with neutral emotional valence) are likely related to a frequency threshold separating positive and negative effect located between 6.6 and 30occ/h; any use of ICT with a frequency higher than this threshold during the lectures reduces their capacity of learning. In practice, this threshold is higher as most of the time students are concerned by emotional non-class related distractors.

A relevant solution for teachers could be to engage themselves in the elaboration of an integrated environmental learning [14] incorporating adapted content into courses and especially creating an appropriate environment on the basis of the use of ICT. As noticed by Gökalp [52] in 2013, "the materials allowing users to engage in an entertaining activity may result in a higher success" (p. 301). Furthermore, his findings highlighted "the importance of having mobile-based versions of instructional materials. Instructional designers should therefore place greater emphasis on the production of instructional materials that use mobile devices" (p. 301). In a similar perspective, web-based blended courses adopting online learning, mobile technologies and other ICT resources [11] could be a relevant resource. Dahlstrom et al.'s report [2] of 2012 concluded that blended learning had become the norm for students: "students say that these environments best support how they learn" (p. 7).

One of the limits of the present study is that data only reflects the ICT use among one kind of population of students in Human Science during one kind of academic lecture within the British culture. We may assume that it could be different for a population of physicists or in another country. Even though a similarity was noticed between the present results and Duncan et al.'s report [6] (2012), another limit lies in that the content of the lecture may have an impact on the use of ICT; for example, a boring lecture may engage some students to check their sms or email instead of writing on their notebook; in these conditions, the observer would likely see more ICT users. This parameter regarding the lecture content was not taken into account. Unfortunately, no other data was found in the literature regarding this point for UK.


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## Appendix

List of neutral sms used during experiment with group 3:

- Hi, where are you? Are you free now?
- How is the weather?
- Don't you feel it is cold?
- And now, where are you?
- At what time are you free?

## References


[1] K. K., Myers, and K. Sadaghiani, "Millennials in the workplace: A communication perspective on millennials' organizational relationships and performance". Journal of Business and Psychology, vol.25(2), 2010, pp.225-238.

[2] E. Dahlstrom, J. D. Walker, and C. Dziuban, ECAR study of undergraduate students and information technology, 2012. Boulder, CO: Educause Center for Applied Research. 2012.

[3] C. B. Fried, "In-class laptop use and its effects on student learning". Computers and Education, vol.50(3), 2008, pp.906-914.

[4] Ph. Fauquet-Alekhine, "Informationand Communication Technologies vs Education and Training: Contribution to understand the Millennials' generational effect", Proc. of the International Conference on Electrical, Computer, Electronics and Communication Engineering, Venezia, IT, vol.80, 2013, August, pp.358-363

[5] Ph. Fauquet-Alekhine, "Learners' behavior in teaching context: characterizing the use of Information and Communication Technologies", Proceedings of the 1st International Science and Applied Research Conference Social Psychology in Education Space, Moscow, Russia, 2013, October, pp.262-264 .

[6] D. K. Duncan, A. R. Hoekstra, and B. R. Wilcox, "Digital devices, distraction, and student performance: Does In-Class cell phone use reduce learning?". Astronomy education review, vol.11(1), 2012, pp.010108.

[7] A. Demb, D. Erickson, and S. Hawkins-Wilding, "The laptop alternative: Student reactions and strategic implications". Computers and Education, vol.43(4), 2004, pp.383-401.

[8] D. M. Sanbonmatsu, D. L. Strayer, N. Medeiros-Ward, and J. M. Watson, "Who multi-tasks and why? Multi-tasking ability, perceived multi-tasking ability, impulsivity, and sensation seeking". PloS one, vol.8(1), 2013, pp.e54402.

[9] E. Ophir, C. Nass, and A. D. Wagner, "Cognitive control in media multitaskers". Proceedings of the National Academy of Sciences, vol.106(37), 2009, pp.15583-15587.

[10] D. L. Strayer, J. M. Watson, and F. A. Drews, "Cognitive distraction while multitasking in the automobile". Psychology of Learning and Motivation-Advances in Research and Theory, vol.54, 2011, pp.29-58.

[11] P. Moskal, C. Dziuban, and J. Hartman, "Blended learning: A dangerous idea?". The Internet and Higher Education, vol.18, 2013, pp.15-23.

[12] F. Sana, T. Weston, and N. J. Cepeda, "Laptop multitasking hinders classroom learning for both users and nearby peers". Computers and Education, vol.62, 2013, pp.24-31.

[13] H. Li, Y. Cui, X. Bai, and S. Davis, "The Impact of Web browsing on classroom learning performance". Issues in Information Systems, vol.11, 2010, pp.460-466

[14] K. D. Su, "An Intensive ICT-Integrated environmental learning strategy for enhancing student performance". International Journal of Environmental and Science Education, vol.6(1), 2011, pp.39-58.

[15] R. L. Bannerman, E. V.Temminck, , and A. Sahraie, "Emotional stimuli capture spatial attention but do not modulate spatial memory". Vision research, vol.65, 2012, pp.12-20.

[16] M. Chan, and A. Singhal, (2013). "The emotional side of cognitive distraction: implications for road safety". Accident Analysis and Prevention, vol.50, pp.147-154.

[17] E.A. Kensinger, and S. Corkin, "Memory enhancement for emotional words: are emotional words more vividly remembered than neutral words?", Memory and Cognition vol.31, 2003, pp.1169-1180.

[18] T. Sharot, E.A. Phelps, "How arousal modulates memory: disentangling the effects of attention and retention". Cognitive, Affective, and Behavioral Neuroscience, vol.4, 2004, pp.294-306.

[19] D. Talmi, A.K. Anderson, L. Riggs, J.B. Caplan, and M. Moscovitch, "Immediate memory consequences of the effect of emotion on attention to pictures". Learning and Memory, vol.15, 2008, pp.172-182.

[20] J. M. Kraushaar, and D. C. Novak, "Examining the effects of student multitasking with laptops during the lecture". Journal of Information Systems Education, vol.21, 2010, pp.241-251.

[21] S. P. Banbury, W. J. Macken, , S. Tremblay, and D. M. Jones, "Auditory distraction and short-term memory: Phenomena and practical implications". Human Factors: The Journal of the Human Factors and Ergonomics Society, vol.43(1), 2001, pp.12-29.

[22] K. H. Bäuml, S. Hanslmayr, B. Pastötter, and W. Klimesch, "Oscillatory correlates of intentional updating in episodic memory". NeuroImage, vol.41(2), 2008, pp.596-604.

[23] K. M. Divis, and A. S. Benjamin, "Retrieval speeds context fluctuation: Why semantic generation enhances later learning but hinders prior learning". Memory and cognition, vol.42(7), 2014, pp.1049-1062.

[24] E. Dhooge, W. D. Baene, and R. J. Hartsuiker, "A late locus of the distractor frequency effect in picture–word interference: Evidence from event-related potentials". Brain and language, vol.124(3), 2013, pp.232-237.

[25] A. Andreopoulos, and J. K. Tsotsos, "50 Years of object recognition: Directions forward". Computer Vision and Image Understanding, vol.117(8), 2013, pp.827-891.

[26] D. J. Schwerha, S. F. Wiker, and M. Jaraiedi, "Effect of distractors, age, and level of education upon psychomotor task learning". International Journal of Industrial Ergonomics, vol.37(9), 2007, pp.801-809.

[27] G. M. Fitch, S. A. Soccolich, F. Guo, J. McClafferty, Y. Fang, R. L. Olson, ... and T. A. Dingus, The impact of hand-held and hands-free cell phone use on driving performance and safety-critical event risk. (No. DOT HS 811 757). 2013.

[28] S. G. Hosking, K. L. Young, and M. A. Regan, The effect of text messaging on young novice drivers performance. (Accident research center. Monash Un. Report No. : 246). 2006.

[29] C. J. Patten, A. Kircher, J. Östlund, and L. Nilsson, "Using mobile telephones: cognitive workload and attention resource allocation". Accident analysis and prevention, vol.36(3), 2004, pp.341-350.

[30] A. Roelofs, V. Piai, and H. Schriefers, "Selective attention and distractor frequency in naming performance: Comment on Dhooge and Hartsuiker (2010)". Journal of Experimental Psychology: Learning, Memory, and Cognition, vol.37(4), 2011, pp.1032-1038.

[31] R. Rosenberger, "An argument against 'No-Look Texting' while driving". Technology and Society Magazine, IEEE, vol.32(1), 2013, pp.53-59.

[32] H. Hembrooke, and G. Gay, " The laptop and the lecture: The effects of multitasking in learning environments". Journal of Computing in Higher Education, vol.15(1), 2003, pp.46-64.

[33] Y. Ellis, B. Daniels, and A. Jauregui, "The effect of multitasking on the grade performance of business students". Research in Higher Education Journal, vol.8(1). 2010.

[34] L. L. Bowman, L. E. Levine, B. M. Waite, and M. Gendron, "Can students really multitask? An experimental study of instant messaging while reading". Computers and Education, vol.54(4), 2010, pp.927-931.

[35] E. Wood, L. Zivcakova, P. Gentile, K. Archer, D. De Pasquale, and A. Nosko, "Examining the impact of off-task multi-tasking with technology on real-time classroom learning". Computers and Education, vol.58(1), 2012, pp.365-374.

[36] A. D. Froese, C. N. Carpenter, D. A. Inman, J. R. Schooley, R. B. Barnes, P. W. Brecht, and J. D. Chacon, "Effects of classroom cell phone use on expected and ectual learning". College Student Journal, vol.46(2), 2012, pp.323-332.

[37] J. H. Kuznekoff, and S. Titsworth, "The impact of mobile phone usage on student learning", Communication Education, vol.62(3), 2013, pp.233-252.

[38] H. Pashler, S. H. Kang, and R. Y. Ip, (2013). "Does multitasking impair studying? Depends on Timing". Applied Cognitive Psychology, vol.27(5), pp.593-599.

[39] B. S. Bloom, M. D. Engelhart, E. J. Furst, W. H. Hill, and D. R. Krathwohl, Taxonomy of educational objectives: the classification of educational goals; Handbook I: Cognitive Domain". New York, Longmans, Green. 1956.

[40] D. R. Krathwohl, "A revision of bloom's taxonomy: An overview", Theory into Practice, vol.41(4), 2002, pp.212-218.

[41] T. Gavrilova, E. Strakhovitch, and I. Leshcheva, "Ontologies for project management teaching". Joint Proceedings of the Work-in-Progress Poster and Invited Young Researcher Symposium at the 18th International Conference on Computers in Education. Putrajaya, Malaysia, 2010, pp.7-9.

[42] I. Leshcheva, D. Gorovaya, and D. Leshchev, "Ontology-based Assessment Technique", Proceedings of the 2nd International Workshop on Semantic Web Applications in Higher Education (SemHE'10), Southampton, UK. 2010, November-December. Retrieved from http://eprints.soton.ac.uk/271753/1/semhe10-leshcheva-et-al.pdf

[43] S. Grussendorf, Device ownership, 'BYOD' and social media for learning. London: LSE CLT/IMT report. 2013.

[44] L. D. Rosen, A. F. Lim, L. M. Carrier, and N. A. Cheever, "An empirical examination of the educational impact of text message-induced task switching in the classroom: Educational implications and strategies to enhance learning". Psicología Educativa, vol.17(2), 2011, pp.63-177.

[45] K. Foerde, B. J. Knowlton, and R. A. Poldrack, "Modulation of competing memory systems by distraction". Proceedings of the National Academy of Sciences, vol.103(31), 2006, pp.11778-11783.

[46] R. E. Mayer, and R. Moreno, "Nine ways to reduce cognitive load in multimedia learning". Educational psychologist, vol.38(1), 2003, pp.43-52.

[47] C.D. Wickens, Engineering Psychology and Human Performance (vol. 2). New York: HarperCollins. 1992.

[48] C.D. Wickens, and J.G. Hollands, Engineering psychology and Human Performance (third ed.). Upper Saddle River, NJ: Prentice-Hall. 2000.

[49] S. Y. Mousavi, R. Low, and J. Sweller, "Reducing cognitive load by mixing auditory and visual presentation modes". Journal of educational psychology, vol.87(2), 1995, pp.319-334.

[50] A. Liebl, J. Haller, B. Jödicke, H. Baumgartner, S. Schlittmeier, and J. Hellbrück, "Combined effects of acoustic and visual distraction on cognitive performance and well-being". Applied ergonomics, vol.43(2), 2012, pp.424-434.

[51] Y. Diao, P. Chandler, and J. Sweller, "The effect of written text on comprehension of spoken English as a foreign language". The American journal of psychology, 2007, pp.237-261.

[52] M. S. Gökalp, "Perceptions of the internet and education: A study with Physics education website users". International Journal of Environmental and Science Education, 8(2), 2013, pp.289-302.

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