Examining The Influence of Interruptions in Online Learning on Student's Perceptions And Comprehension

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Abstract

The presented research focuses on examining the influence of interruptions in online learning on student's perceptions and comprehension. We conducted an experiment with 45 participants. Each participant watched one lecture that belonged to one of the two experimental groups, a lecture with interruptions or a lecture without interruptions. While watching the lecture, the eye movements of the participants were recorded using an eye tracking device. After watching the lecture, the participants were asked to answer two questionnaires, knowledge questionnaire and subjective questionnaire. We found that interruptions do harm the comprehension of the delivered material when they occur and moreover, they cause an "after affects", harming the comprehension of the studied material even at times they do not occur at all. In addition, we found that interruptions attract the student's attention when they occur and at the same time causing a feeling of aversion and a desire to avoid focusing on them. Which may eventually cause negative subjective perceptions and to harm the understanding of the studied material. The world of online learning has developed a lot in 2020 and in fact the whole world has been forced to switch to online learning. Therefore, this technology must be optimized and improved.

Keywords
Online Learning, Interruptions, Comprehension, Eye Tracker, Fixation

Introduction
A major global change happened during COVID-19 crises. The world population was required to maintain social distance, following medically instructed quarantine process. This situation had influence on many aspects, including the field of learning and the academic education. Face-to-face learning has been replaced by online learning, and educators need to change their setting (Katz & Kedem-Yemini 2021). The online learning is the new world's mode of learning and despite the new problems, there are lucrative sides to online teaching and learning (Dhawan, 2020). With the help of online teaching modes, educators can reach a large number of students at any time and in any part of the world, thus it increases accessibility, diversity and bridges gaps in world's population. There is no doubt that online learning and teaching will remain with us long beyond the period of COVID-19. Therefore, it is important to examine the **quality** of online teaching and learning at this stage.

Nowadays, in the context of education, there is a wide use of video conference software (VCS) such as Zoom, WebEx and Google Meet. These platforms enable participants to see each other and communicate orally though they are in separate locations. In these online learning environments, students watch and listen to the lecturer with presentations' assistance. The level of knowledge and understanding of the material delivered in an online lecture

can be affected by a variety of factors. Chen et al. (2021) found that interruptions in an online lecture caused by visual stimulation are the main reason for the decline in academic performance. Visual and auditory stimuliunrelated to the learning subject may affect the level of understanding, for example, certain elements that enter the camera angle and noises originating from the lecturer's environment may interrupt and compete with the content delivered by the lecturer, and the students' attention may be distracted from the main learning content.
In this research we focus on the effect of disturbances and interruptions in the background of the lecturer in online learning on student's attention, subjective perceptions, and their comprehension of the delivered material. We wish to shed light on the consequences of these "background noise", to optimize this form of distance learning. If interruptions have a negative impact on perceptions towards the learning process, and detrimental consequences on learnability and comprehension, education practitioners and lecturers will need to reduce these noises to create an optimal online learning environment.

1.1 Objectives

Our main objective was to examine the way interruptions in the background of the lecturer's window affect student's attention, comprehension, and subjective perceptions of the learning process and material.

Attention: We wanted to evaluate whether students' attention is affected by the occurrence of interruptions during the online lecture. We expect that students who watch an online lecture with background interruptions in the lecturer's area, will have attention disruptions. Therefore, whenever an interruption occurs, their gaze will be diverted faster to the origin of the interruption (the lecturer area on the screen). Also, they will keep their gaze on the presentation area longer in moments when no interruptions occur in the lecturer's area.

Comprehension: We wish to investigate whether students that are exposed to a lecture with background interruptions demonstrate less knowledge of the content delivered compared to students exposed to a lecture without background interruptions. Also, we wish to further invest whether students who watch a recorded lecture that contain interruptions demonstrate less knowledge of the content delivered in the lecture at times when interruptions occurred in comparison to students who watch a recorded lecture with no interruptions during the delivery of this specific content. Another investigation was for finding out whether there are "after affects" of background interruptions, causing students in a lecture with background interruptions to acquire less knowledge of the content delivered also at times when no interruptions occur compared to students in an online lecture with no interruptions at all. This is because the student may have an expectation of future interruptions, which may cause a lot of attention to be paid to the place where the previous interruptions came from, at the expense of the presentation in which the educational material is presented.

2. Literature Review

2.1. Retention of the delivered material

Muljana and Luo (2019) claim that despite the advantages of online learning, it suffers from a low comprehension rate. The number of dropouts in online learning environments is higher than in a traditional learning environment. The rate of completing online courses is about 8-14% lower than in face-to-face courses. According to Federman (2019) interruptions occurring in an online lecture harm the coding and understanding of the information delivered in the lecture. Unexpected and uncontrollable disturbances cause an information overload that leads to high stress levels among the students and as a result to cognitive fatigue. At the end, the cognitive fatigue together with the high stress levels, may lead to a negative feeling of the students around learning and, accordingly, to damage their academic achievements. Moon and Ryu (2021) found that visual disturbances that occur during an online lecture affect the recall and understanding of the material delivered in the online lecture.

2.2. Eye tracker

According to Wang et al. (2018), more than 80% of the information the human brain receives comes from the eyes. Furthermore, Poole and Ball (2006) claimed that the eyes provide a window to many cognitive aspects and accordingly there are many possibilities for statistical analyzes of eye movements that can be a main tool in usability studies in the field of human-computer interaction in particular. Federman (2019) found in her research that interruptions occurring in an online lecture harm the encoding and understanding of the information conveyed in the lecture. In addition, she found that unexpected and uncontrollable disturbances cause an information overload that leads to high stress levels among the students and as a result to cognitive fatigue. The fatigue together with the high stress levels, may lead to a negative subjective feeling of the students around learning and, accordingly, to damage to academic achievements. Following this, the field of human-computer interaction should strive to keep the online learning environment as friendly as possible (Lewandowska et al. 2022). The use of an eye tracking device makes it possible to define specific areas in which the researcher wishes to study certain behaviors in these areas. Measures regarding those indicators are Area of Interest (AOI) and Time of Interest (TOI), defined as following:

Area of Interest- AOI
Mu et al., (2019) define the area of interest as a tool for selecting an area of a certain stimulus on which we want to generate data using the eye tracking device, and that the division into areas of interest (hereafter AOI) is an initial and decisive step. Defining AOIs, specific areas on the displayed screen, which are used as a source of information, is critical for achieving significant results (Ellis 2009; Borys and Plechawska-Wójcik 2017). AOIs must be defined according to the specific task type being tested based on the form of visual scanning required to complete the task and the interface used (Ellis 2009), and based on the semantic information of the presented stimulus (Borys and Plechawska-Wójcik 2017).

Time of Interest- TOI
In a study carried out by Nugrahaningsih et al. (2021) for evaluating different learning styles in online learning using an eye tracking device, participants watched a presentation that contained 10 different slides. In order to analyze the different learning styles, the researchers divided the timeline of the presentation into ten distinct strips of time of interest (TOI) and for each defined TOI a certain behavior was studied. In another study carried out by Zu et al. (2022) for evaluating the differences in thinking flexibility between novices and experts based on eye tracking, they defined 12 TOIs in order to control the variables the eye tracking device will produce.

3. Methods
In this study we conducted an experiment in the usability laboratory of the Department of Industrial Engineering and Management at SCE College, Israel. We performed a controlled experiment using a between-within subject experimental design. We manipulated one variable, whether there were background interruptions during an online lecture in Zoom and observed its impact on student's attention and comprehension. The subjects were 45 undergraduate students specializing in Information Systems, between the ages of 20-35. As an incentive for participating in the experiment, the students were offered 3 bonus points for the final grade in the course "Human Computer Interactions". All the students watched a 30 minute Zoom lecture, with a new subject (that was never offer before in the College), while eye-tracker followed their eye movement and then had to answer 2 questionaries.

Between-subjects – experimental group: 22 students watched a pre-recorded lecture that did not contain any background interruptions, while 23 students watched a pre-recorded lecture with some background interruptions in the lecturer's area on the screen, during the lecture. The lecturer, the presentation slides and all the spoken content delivered were identical for both presentations, to achieve control over the between-subject manipulation: whether there were interruptions or not. The experiment was conducted to each participant separately at a different time, meaning that in each run of the experiment there was only one participant in the laboratory. The conditions in the laboratory were exactly the same for each subject, including the instructions of the experiment, and what occurred in all phases, in order to remove unwanted interfering variables.

The lecture was about the topic of Process mining, and all the students that participated came with no prior knowledge about this topic (Kedem-Yemini, 2020). Importantly, the IRB (ethics committee) of the academic institute in which the experiment was conducted approved the research project (approval number 17), including the experimental task, the testing procedure, and the collection of data. Each experiment was allotted 45 minutes. Each participant went through the exact same stages in the exact order and the same explanation was given in each of the stages to each participant. Prior to the experiment, each participant signed a written consent to participate in the study, and then a calibration phase was performed for the purpose of synchronizing the eye tracking device to each participant. Next, the participants watched the pre-recorded lecture. Lastly, they were asked to answer the knowledge questionnaire and a subjective questionnaire of subjective perceptions regarding the lecture.

Within-subjects - Time of interest: We made a distinction between lecture phases in which an interruption occurred and phases with no occurrence of any background interruption. Each phase, which was considered a time of interest (TOI) in the lecture, was defined using a start event and an end event defined in the data processing step, therefore creating a "strip". In our research we defined a total of 15 strips of distinct TOIs, 5 out of them contained interruptions, therefore labeled as type I (for interruptions), and the other 10 strips without interruptions were labeled as type N (Non-interruptions). The time range of the strips (TOIs) ranged from 35 seconds up to 2 minutes and 18 seconds.

4. Data Collection

The data was collected using the Tobii Pro Lab eye tracking device and using Google Sheets to collect the data on the participants' answers to the questionnaires. We tested the impact of the background interruptions on the student's attention with a Tobii Pro Nano eye tracking device. The eye tracking device was placed horizontally at the bottom of the computer monitor and at a distance of about 60 centimeters from the viewer, following the Tobii instructions (2011), since this is an optimal viewing angle that covers the entire monitor allowing the eye tracker to collect as many data as possible. All data, set and collected by the eye tracking device, was later processed in Tobii Pro Lab software. The resolution of the videos the participants watched was 1080x1920 and it was adjusted to the monitor resolution. The sample collection frequency was set to 60Hz, which means that every 16.67 milliseconds the eye tracking device collected a sample. Due to high sampling frequency and the duration of each recorded lecture, approximately 23 minutes, among 45 participants, a very large amount of raw information (big data) was produced and then processed and analyzed to answer the research hypotheses.

The database contained independent variables and dependent variables, collected from several different platforms and finally compiled into one file on which all the statistical analyzes were performed in SPSS software.

4.1. Independent Variables

Two independent variables were tested:

- Between-subjects, the experimental group. All students watched a pre-recorded lecture about Process mining. One recording was of a lecture in which visual and audio background interruptions embedded in 5 strips out of 15 (22 subjects), and the other was the same lecture without interruptions at all (23 subjects). Each participant was randomly allocated into one experimental group.
- Within-subjects, TOI/Strips- Each experimental session (with/without interruptions) was divided into 15 strips as described in the Method section. In the group with interruptions there were 5 strips with interruptions (type I – stripes 3, 5, 7, 9, 11) and 10 strips with no interruptions (type N).

4.2. Dependent variables extracted from the knowledge questionnaire

Referring to the knowledge test, a correct answer to a Process mining question was assigned a value of 1 while a wrong answer was assigned a value of 0. A correct answer earned the student 10 points, and an incorrect answer did not add its points to the score. The final score for each participant was calculated as a sum of those values. The knowledge questionnaire has 10 questions, each of which received a weight of 10 points, so the maximum test score was 100 points. Also, a weighted score was given to three questions that examined content during which interruptions occurred in the lecture (questions 5-7). This weighted score was calculated by adding the values (1 for a correct answer and 0 for a wrong answer) obtained for these questions, dividing the sum by 3 and multiplying the obtained value by 100. Accordingly, the weighted score calculated for the seven questions that tested the comprehension of material that was delivered with no interruptions (1-4, 8-10) was calculated by adding the scores of these questions, dividing the amount calculated by 7 and multiplying the value obtained by 100. Table 1 shows the ten knowledge questionnaire items alongside stating whether a background interruption occurred while delivering this knowledge.

Table 1. The question items in the knowledge questionnaire

Question	The knowledge question regarding process mining	Was there an interruption?
1	What is computerized event log?	No
2	What is the purpose of process mining?	No
3	What is process mining based on?	No
4	What is an event?	No
5	What is a variant?	Yes
6	Modeling the data log in process mining is	Yes
7	Which of the following is mandatory in process mining analysis?	Yes
8	Which of the following would be found in a process mining analysis?	No
9	What does dark blue color indicate in the process map diagram?	No
10	What is a quality deviation in the investigated process?	No

4.3. Dependent variables extracted from the eye tracker device

The second set of dependent variables was data generated from the Tobii Pro Lab software based on the data collected from the eye tracking device. We had two files for eye tracker data: a "Data Export" file containing data for each subject, and a "Data Metrics" file that stored data from all experiments according to the defined TOIs. Since we defined 2 AOIs and 15 TOIs, the resulting outputs are TOI and AOI based. One matrix used is the matrix of fixations in the AOI allowed us to calculate the indices of fixations in an AOI based on intervals where each interval is displayed in a separate row. According to the Pro Lab software manual (2021), gaze fixation is based on the angular velocity at a specific data point. The angular velocity is obtained with the help of a velocity calculation function that is calculated using 3 points: the position of the eyes and two points of view on the stimulus that is shown. A threshold value is set for this angular velocity for each data sample. A sample with a value lower than the threshold value is cataloged as a fixation while a sample with an angular velocity value higher than the threshold value is cataloged as a saccade. The eye tracker data is considered big data for each user, and we indeed collected a vast amount of data. Due to paper length limit, in the current paper we focus exclusively on only few dependent variables, which are presented in table 2.

Table 2. Dependent variables extracted from the eye tracker device

Metric	Description	Indicators	literature
Number of fixations in an AOI	The number of fixations occurring in an AOI during an interval.	1. The higher the cognitive load, the smaller the number of fixations. 2. A larger number of fixations in the same observation time will increase the observer's capacity to recognize and memorize what is represented on the image. 3. Mind wandering was associated with an increased allocation of fixations to the instructor's image. 4. More fixations on a specified area signify that it is more perceptible ,or more significant to the viewer than other areas.	1. Soler-Dominguez, J. L., Camba, J. D., Contero, M., & Alcañiz, M. (2017, July). 2. Dupont, L., Antrop, M., & Van Eetvelde, V. (2014). 3. Zhang, H., Miller, K. F., Sun, X., & Cortina, K. S. (2020). 4. Jacob, R. J., & Karn, K. S. (2003).
Time until first fixation	The time to the first fixation inside an AOI during an interval.	Faster time to first-fixation on an object or area mean that it has better attention-getting properties.	Jacob, R. J., & Karn, K. S. (2003).
Duration of first fixation	The duration of the first fixation inside an AOI during an interval	Longer fixation durations indicate difficulty in extracting information	Dupont, L., Antrop, M., & Van Eetvelde, V. (2014).

5. Results and Discussion

In this section we will present the main findings and discuss the consequences and implications of our findings. First we will examine the results regarding retaining of the delivered materials in the lecture and then the influence of interruptions in attention.

5.1 Retention of the delivered materials in the lecture

In this section we will show three main findings: The effects of background interruptions during an online lecture on the overall comprehension, on comprehension when interruption occurs and when no interruption occurs.

5.1.1. The effects of background interruptions during an online lecture on the overall comprehension of the topic

The score given in the knowledge questionnaire is an interval variable that can have values ranging 0-100. The results of the knowledge questionnaire show that among the group that watched the lecture with interruptions, the lowest score received was 20 and the highest score received was 100. Comparably, among the group that watched the lecture without interruptions, the lowest score received was 40 and the highest score received was 100. For investigating whether students that are exposed to a lecture with background interruptions demonstrate less knowledge of the content delivered compared to students exposed to a lecture without background interruptions was performed a T-test for independent samples. Table 3 shows the results of the T-test.

Table 3. T-test examining the differences in the overall knowledge scores according to the experimental groups

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
		F	Sig.	t	df	Significance		Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
						One-Sided p	Two-Sided p			Lower	Upper
Final grades	Equal variances assumed	31.571	<.001	4.500	673	<.001	<.001	6.700	1.489	3.776	9.623
	Equal variances not assumed			4.527	639.369	<.001	<.001	6.700	1.480	3.794	9.606

The results show a significant difference between the overall scores of the knowledge test between students who watched the lecture without interruptions and students who watched the lecture with interruptions (t(639)=4.500, p<0.001). The descriptive statistics show that students who watched a recorded lecture without interruptions (M=64.09, std = 16.445) demonstrated more knowledge of the materials delivered in the lecture, than students who watched a recorded lecture with interruptions (M=57.39, std = 21.745). This result is in the expected direction of the hypothesis. The average score of the knowledge questionnaire received for the group of students who watched the online lecture with interruptions is indeed lower than the average score of the knowledge questionnaire received for the group of students who watched the lecture without interruptions. This finding is also consistent with the findings of Zhang et al., (2020) who found a relationship between interruptions in online learning and understanding the material taught in the lecture. The more the student's attention is distracted, the less the understanding of the studied material. Also, an increase in the distraction will cause a decrease in the retention of the studied material.

5.1.2. The effects of background interruptions during an online lecture on comprehension when interruption occurs

In addition to examining whether there are differences between the experimental groups in the overall Process mining knowledge test, we were interested in testing whether there is a statistical significance in the weighted scores that were calculated for the questionnaire items (5-7) that refer to content that during its delivery, there were interruptions in one experimental group but not at the other. We conducted a T-test to find out whether there were any differences between the experimental groups in relation to the weighted score of those questions. We expected that students who learn from a recorded lecture with interruptions will demonstrate less knowledge of the contents delivered during the interruptions. Table 4 shows the results of the T-test. It demonstrates a significant difference between the scores of students that belong to different experimental groups (group with interruptions on five strips versus group with no interruptions at any strip) in the scores of the questions that refer to content that was delivered with interruptions in the interruption-group (5-7): (t(673)=3.735, p<0.001).

The descriptive statistics show that students who watched a recorded lecture without interruptions did better in the test items that referred to materials that were delivered with interruptions in the other experimental group (M=54.545, std = 29.424), in comparison to students who watched the lecture with interruptions during the contents that these items checked (M=46.377, std = 27.385). This was of course an expected result, derived from our manipulation on these three knowledge items. The group that had interruptions during the delivery of the material that these three questions tested, showed less knowledge in these questions than the group that had no interruptions during the delivery of the material that these questions tested.

Table 4. T-test examining the differences between the experimental groups in the scores of questions referring to content in which interruptions occurred

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
grades for knowledge items with interruptions	Equal variances assumed	2.912	.088	3.735	673	<.001	<.001	8.169	2.187	3.875	12.462
	Equal variances not assumed			3.730	664.047	<.001	<.001	8.169	2.190	3.868	12.469

Students who watched a lecture with interruptions demonstrated less knowledge of the content delivered in the lecture during times when interruptions occurred compared to students who watched a lecture without interruptions. This result is in the direction of the findings of Chen et al. (2021) who showed that interruptions in online learning harm the understanding of the content learned during it, and that interruptions caused by visual stimulation are the main cause of decreased academic performance.

5.1.3. The effects of background interruptions during an online lecture on comprehension when no interruption occurs

We were interested to find out whether there are "after affects" of background interruptions, causing students in a lecture with background interruptions to acquire less knowledge of the content delivered also at times when no interruptions occur, compared to students in an online lecture with no interruptions at all. We expected that students who watch an online lecture that have interruptions from time to time will demonstrate less knowledge of the contents delivered also at times when interruptions do not occur, because they will pay more attention to the place where the previous interruptions came from, at the expense of the presentation in which the educational material is presented. We ran a T-test for independent samples, results are shown in Table 5.

Table 5. T-test examining the differences between the experimental groups in the scores of questions referring to content in which no interruptions occurred

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means							
						Significance				95% Confidence Interval of the Difference	
		F	Sig.	t	df	One-Sided p	Two-Sided p	Mean Difference	Std. Error Difference	Lower	Upper
grades for knowledge items with no interruptions	Equal variances assumed	8.863	.003	3.751	673	<.001	<.001	6.07	1.618	2.892	9.247
	Equal variances not assumed			3.768	657.220	<.001	<.001	6.07	1.610	2.906	9.233

The results show a significant difference between the scores of students that belong to different experimental groups (group with interruptions on five strips versus group with no interruptions at any strip) in the scores of the questions that refer to content that was delivered with no interruptions (1-4, 8-9, 10): ($t(673)=3.751$, $p<0.001$). Indeed, a knowledge test indicated that there are differences in the weighted questions that refer to content that was delivered with no interruptions, even though seemingly nothing occurred in the background to interrupt the acquiring of knowledge when it was delivered. The descriptive statistics show that students who watched a recorded lecture without interruptions (M=68.181, std = 18.77) demonstrated more knowledge of the materials delivered in the lecture with no interruptions, than students who watched a recorded lecture with interruptions (M=62.111, std = 22.95). This result is in the expected direction of the hypothesis, indicating that there is probably an "after effect" to interferences in the background.

This is also consistent with the findings of Hasan and Khan (2020) that distractions may harm the understanding of the studied material and that the time periods after an interruption are characterized by a decrease in the retention of the studied material. Understanding material taught in the lecture, at times when no interruptions occurred at all, was damaged as a result of interruptions that occurred in the lecture at other times. Interruptions affect the understanding of the material studied even at times when they do not occur at all, indicating a kind of lasting effect, an "after effect".

5.2 The influence of interruptions in attention – eye tracker data

5.2.1. The time until a first fixation and its duration for a recorded lecture that contained interruptions

The time until a first fixation occurs on the AOI lecturer window, and the duration of the fixation on that window are interval-type dependent variables, measured in milliseconds. The distribution of these two dependent variables were tested and found to be normal, verifying compliance with the basic assumptions for using the analysis of variance test. As aforementioned in the Method section, we defined 15 strips of TOIs. These strips are an independent variable of nominal type. According to Poole and Ball (2006), shorter times until a first fixation on an object in an AOI indicate that AOI has characteristics that attract attention.

Dupont et al. (2014) claim that longer first fixation durations indicate a difficulty in extracting information. Accordingly, we expected that during occurrences of interruptions, students who were in the group with background interruptions in the lecture's window, will pay attention to the lecturer faster (the time until the first fixation will be shorter) but will keep their gaze on the lecturer (duration of the first fixation) less, in comparison to TOIs when there are no interruptions. We performed an analysis of variance test, and for this, the strips of TOIs, were divided into two categories: 1. strips during which an interruption occurred (cataloged as INT to mark an interruption) 2. Strips during which no interruptions occurred (cataloged as NONINT to mark a non-interruption). Table 6 shows the descriptive statistics and Table 7 shows the results of the variance test to examine the effect of the strip's type on the time until a first fixation on the lecturer and its duration.

Table 6. Descriptive statistics time to first fixation on the lecturer and its duration according to the type of strip category

Descriptive Statistics

	INT	Mean	Std. Deviation	N
Time until a first fix.lecturer	INT	3165.96	6340.955	114
	NONINT	17436.05	23398.508	226
	Total	12651.38	20549.927	340
dur of first fix.lecturer	INT	501.82	559.795	114
	NONINT	515.54	671.201	226
	Total	510.94	635.225	340

Table 7. Analysis of variance to examine the effect of the strip's type on the time to first fixation on the lecturer and its duration

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.
Model	Time until a first fix.lecturer	69850264216.778[a]	2	34925132108.389	92.420	<.001
	dur of first fix.lecturer	88773951.727[b]	2	44386975.863	109.689	<.001
INT	Time until a first fix.lecturer	69850264216.778	2	34925132108.389	92.420	<.001
	dur of first fix.lecturer	88773951.727	2	44386975.863	109.689	<.001
Error	Time to first fix.lecturer	127728759547.222	338	377895738.305		
	dur of first fix.lecturer	136775923.273	338	404662.495		
Total	Time to first fix.lecturer	197579023764	340			
	dur of first fix.lecturer	225549875	340			

Note: significant values are marked through bold.

a. R Squared = .354 (Adjusted R Squared = .350)
b. R Squared = .394 (Adjusted R Squared = .390)

Results show that the time until a first fixation on the lecturer in the strips with an interruption is statistically significant (F(2,338)=92.42, p<0.001)). The time until a first fixation in the strips with an interruption (M=3165.96, SD=6340.955) is shorter than the time until a first fixation in non-interruption strips (M=17436.05, SD=23398.508). Thereafter, it was found that the duration of the first fixation on the lecturer in the strips with an interruption is statistically significant (F(2,338)=109.689, p<0.001)). The duration of the first fixation in the strips during which an interruption occurred (M=501.82, SD=559.795) is shorter than the duration of the first fixation in non-interruption strips (M=510.94, SD=671.201).

5.2.2. The relationship between the number of fixations on the lecturer AOI, the presentation AOI and the final knowledge grade

Saiz-Manzanares et al., (2021) showed that the retention of knowledge is linked to the amount of fixations in a certain AOI. Furthermore Sharafi et al. (2018) found that a greater number of fixations dedicated to the stimulus indicates an ineffective learning process and, therefore, an impairment in the understanding of the studied material. Therefore, we performed a Pearson test to find out whether there are relationships between the number of fixations on the lecturer and on the presentation and the grade on the knowledge questionnaire. Results are shown in Table 8.

Table 8. Pearson's test to examine the relationship between the number of fixations on the lecturer and on the presentation and the knowledge questionnaire grade

Correlations

		Num of fix.lecturer	Num of fix.presentation	Final grade
Num of fix.lecturer	Pearson Correlation	1	.240**	.133**
	Sig. (2-tailed)		<.001	<.001
	N	675	675	675
Num of fix.presentation	Pearson Correlation	.240**	1	.048
	Sig. (2-tailed)	<.001		.210
	N	675	675	675
Final grade	Pearson Correlation	.133**	.048	1
	Sig. (2-tailed)	<.001	.210	
	N	675	675	675

**. Correlation is significant at the 0.01 level (2-tailed).

Pearson test results indicate that there is a significance relationship between the number of fixations on the lecturer and the number of fixations on the presentation, and also between the number of fixations on the lecturer and the final grade. No significance statistical relationship was found between the number of fixations on the presentation and the final grade. In order to discover the source of the relationship between the variables, we performed a linear regression test. The dependent variable was the grade in the knowledge questionnaire, and the independent variables were the number of fixations on the lecturer and the number of fixations on the presentation. All variables are interval type. Table 9 presents the model summary.

Table 9. Model summary

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change
1	.133[a]	.018	.016	19.452	.018	12.057	1	673	<.001

a. Predictors: (Constant), Num of fix.lecturer
b. Dependent Variable: Final grade

It appears that there is a relationship between the number of fixations on the lecturer AOI and the knowledge questionnaire grade, but this relationship is a weak relationship (R=0.133). To test the suitability of the model, we examined the results of the variance analysis, as shown in Table 10.

Table 10. Variance analysis to test the suitability of the model

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4561.742	1	4561.742	12.057	<.001[b]
	Residual	254638.258	673	378.363		
	Total	259200.000	674			

a. Dependent Variable: Final grade
b. Predictors: (Constant), Num of fix.lecturer

The analysis of variance shows that the model significantly predicts the value of the knowledge questionnaire score F(1,673)=12.057, P<0.001 and it can be assumed that there is a linear relationship between the amount of gaze fixations on the lecturer and the knowledge questionnaire score. Once significance has been found, we traced the information needed to predict the knowledge questionnaire score. Table 11 shows the table of coefficients.

Table 11.The table of coefficients

Coefficients[a]

Model		Unstandardized Coefficients: B	Unstandardized Coefficients: Std. Error	Standardized Coefficients: Beta	t	Sig.	95.0% Confidence Interval for B: Lower Bound	95.0% Confidence Interval for B: Upper Bound
1	(Constant)	57.842	1.106		52.316	<.001	55.671	60.013
	Num of fix.lecturer	.149	.043	.133	3.472	<.001	.065	.233

a. Dependent Variable: Final grade

From Table 11, it is possible to deduce the regression equation: Final grade=0.149*Num of fix.lecturer+57.842. Therefore, the knowledge grade for each student will increase by a rate of 0.149 for each additional fixation on the lecturer. Finally, to test the question of whether the relationship between the amount of fixations on the lecturer and the knowledge questionnaire score is consistent, we checked homoscedasticity. According to the homoscedasticity assumption, the errors of the linear model may be affected by variables that were not taken into account in the model. This assumption holds when the variables being tested have the same variance. The homoscedasticity assumption is shown in Figure 1.

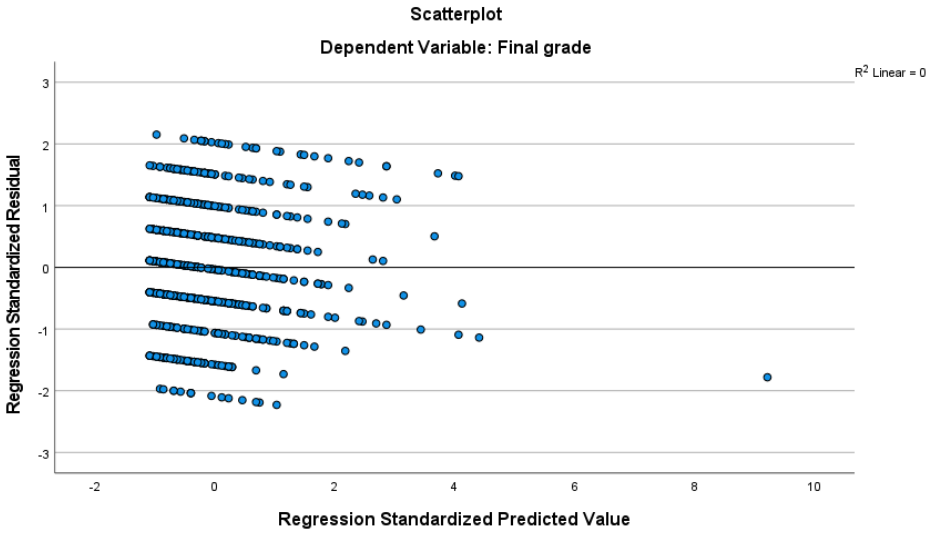

Figure 1. Homoscedasticity between the number of fixations on the lecturer and the knowledge grade

Figure 1 shows the ratio between the residuals that represent the deviation of the values from the model as a ratio of the values of the knowledge questionnaire score, indicating that the assumption of homoscedasticity holds and hence the model is appropriate. This means that the errors in the model that may be affected by variables not considered, have the same variance, meaning that the value of one variable can reliably predict the value of another variable.

Our findings are consistent with those of Chen et al. (2021) that when an interruption occurs suddenly in the visual field, the students' attention will be forced to be distracted and the gaze path of their eyes will be unconsciously influenced to leave one AOI and move to another. Our findings extend the findings of Chen et al. (2021) in that, compared to the strips in which no interruptions occurred, the time until a first fixation on the lecturing area was significantly longer than in the strips during which interruptions occurred. Similar to the findings obtained in the statistical analysis performed, Zhang et al., (2020) found that the students' attention is reflected through two basic and related aspects of eye movements: when to move the eyes and where to move the eyes. Both aspects (when and where) determine that the student's attention is no longer on the task at hand. Furthermore, Zhang et al. (2020) found that the increase in the duration of the first fixation, implies that the visual processing that occurs during the lecture tends to be less efficient, and this is because the students had to spend more time processing information in one AOI before moving to the next AOI.

The findings are consistent with those of Zhang et al. (2020) because in strips with interruption the students shifted their initial gaze to the lecturer area faster but they looked at this area for shorter times than in strips where no interruption occurred. Compared to the strips that did not contain an interruption, the time until the first fixation in the lecturer area was significantly longer than the time to first fixation on the lecturer in the strips during which interruptions occurred. In addition, it can be concluded that an increase in the duration of the first fixation on the lecturer indicates an inefficient visual processing that may be reflected in an inefficient processing of the information presented in the AOI. Therefore, students who strive to process and understand the information delivered to them during a lecture, will try to avoid the source of distraction as quickly as possible. We also can conclude that interruptions causes the student's attention to be diverted and as a result the gaze path will be affected, in such a way that the student is not aware of it at all, from one AOI to other. When an interruption occurs in the lecture's area, from the moment it is detected by the student, she or he will try to avoid it as quickly as possible in order to maintain the level of concentration and will look away from the source of the interruption. Regarding the relationships between the number of fixations on the lecturer, the number of fixations on the presentation and the final knowledge grade, we found that students who during a lecture look more at the lecturer, demonstrate more knowledge of the contents delivered in the lecture than students who looked less at the lecturer's area.

No relationship was found between the number of fixations on the presentation and the knowledge grade. Our findings are consistent with Zhang et al. (2020) who found a relationship between the number of fixations on the lecturer and the number of fixations on the presentation. From the linear regression it emerged that, there is a weak positive relationship between the number of fixations on the lecturer and the knowledge grade, which should reflect the understanding of the studied material. This is contrary to the findings of Zhang et al. (2020) who found that the understanding of the studied material decreases when students do not know where to look and as a result they look more at the lecturer and less at the presentation. Zhang et al. (2020) believed that the students do not follow material delivered in the lecture and they may lose concentration in the lecture and their mind may be distracted from the content of the lecture. In addition, the findings of the linear regression contradict the findings of Sharafi et al. (2015) who found that a greater number of fixations on a certain stimulus indicates that the attempt to understand the information presented or explained in it is ineffective. It is possible that the differences between the findings were obtained due to the nature of dividing the screen of the lecture into AOIs. The division is reflected in the size of the area allocated to each area and its position on the screen.

Accordingly, larger areas of interest cover a larger portion of the screen and as a result will be accompanied by a greater number of fixations. This possible explanation suggests that the size of the AOI has an effect on the number of fixations devoted to it. However, the linear regression findings consistent with the findings of Dupont et al., (2014) who found that a greater number of fixations on an AOI will increase the viewer's ability to understand and remember the material conveyed or explained there. This finding reinforces the claim of Dupont et al., (2014) because they suggested a linear relationship between the amount of fixations on the lecturer and the knowledge gained. As the number of fixations on the lecturer increases, a better understanding of the studied material is achieved, and the knowledge gain increases. This is in line with the Media Richness Theory (MRT) that claim that the ability to convey different types of communication cues simultaneously makes the communication richer and more effective (Daft & Lengel, 1986). Seeing the lecturer's facial expressions adds to the understanding of his or her utterances.

Summarizing the presented results brings us to the conclusions that interruptions during online learning have a negative effect on student's attention. We can add to that that interruptions during online learning have a detrimental effect on the understanding of the course material. Another conclusion is related to the Zoom lecture setting. We can show that looking at the lecturer increases the understanding of the topic.

5.4 Validation

The validation process to the analysis shown in the Results section included the following steps: examination of missing values and errors, preliminary descriptive and frequencies statistics, reliability analysis (Alpha Cronbach), as needed grouping of variables and recoding.

6. Conclusion

In our study, we examined the way in which disturbances affect the students' subjective perceptions of learning and the understanding of the studied material. This research has theoretical and practical contributions. Theoretically, this research attempts to analyze new teaching setting with eye tracker device, and to join this data to the students' understanding and satisfaction. This research also has developed measurements model that can be used in another similar research. It seems that the research in this field has only begun (Kedem-Yemini & Katz, 2021). Mishra et al., (2020) claim that the outbreak of the COVID-19 virus has led to a pedagogical shift to online learning that is gradually expected to replace the formal face-to-face learning system. Through a solid understanding of student's attitudes and the challenges they face in online learning, educational institutions will be able to develop different strategies to assist and optimize the learning system (Aguilera-Hermida 2020). One of the main negative aspects of online learning mentioned among students is the occurrence of interruptions during learning (Hussein et al. 2020).

In addition, we can specify practical recommendations, supported by our research findings. We will present three main practical applications emerged to optimize online learning.

The first conclusion is that interruptions during online learning have a detrimental effect on student's attention. Zhang et al. (2020) claim that most students are not even aware that they are distracted during a lecture. Lecturers teaching online must ensure a physical environment free of distractions and interruptions. They should close the door of the room where they are giving the lecture, and make sure that there are no unnecessary noises (for example by closing windows or devices that make noises). It is better to sit in an environment where there are not many objects in the background (such as decorations), and if there is no such area, lectures can and should use a minimalist digital background that does not overload visually. If there was an unplanned interruption during the teaching, the utterances said must be repeated.

The second is that interruptions during online learning have a detrimental effect on the understanding of the course material. We have found that there is a negative effect of interruptions in an online lecture on the understanding of the material being studied throughout the entire lecture and not only on the materials being studied while interruption occurs. Being aware that interruptions harm comprehension of the studied topic, we recommend that lecturers provide students with additional ways to understand the material taught in the lecture such as writing a lecture summary and opening a forum for questions. On top of that, if a background interruption occurred, the lecturer should ask the students if the utterances during the interruption are understood, and based on their feedback, he or she will know whether to repeat the things or move on with the rest of the lesson.
The third is that it seems that looking at the lecturer increases the understanding of the materials he or she conveys. It is important that the students see the lecturer's face during the lecture. Lecturers are recommended to turn on their camera. Of course, it is not equivalent to the richest face-to-face communication, but certainly comes close.

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Biographies

Adva Epstein holds a bachelor's degree of Industrial Engineer and Management (IE&M) with specialization in Information System and a Master of Industrial Engineer and Management from Sami Shamoon College of Engineering (SCE) in Ashdod, Israel. This study was part of her final project for a master's degree, and this is her first academic paper. She has worked as an IT Engineer for two years and as a project supervisor for 3 years in a major Israeli aerospace and aviation manufacturer, producing aerial and astronautic systems for both military and civilian usage. She is currently working as a process department manager in a solar and green energy company located in California.

Sagit Kedem-Yemini is an Industrial Engineer, proficient in information systems and currently holding two lecturing positions: a tenured lecturer position at Sapir Academic College (Logistics Department) and an adjunct lecturer at Ben Gurion University (both in IE&M and Faculty of Business and Management). Her teaching portfolio is broad, focusing on Enterprise Systems implementation (SAP and Oracle Applications) and derivatives of ERP data collection – from Business Analytics to Process Mining. Additionally, she has extensive experience in academic curriculum development, is head of her department's teaching committee and serves as liaison to the graduation projects unit. Her research interests include Process Mining and its practical applications, ERP relates issues and DSS development. Since 2015 she serves as member of JITCAR Editorial Review Board. Prior to her to academic career, Dr. Kedem-Yemini worked at a global Clean-Room Fab Build-Up Construction Management Company with major clients (such as Intel, Tower Semiconductors, and Teva Pharmaceuticals), where she held various positions, including Logistics Manager, Scheduling Manager and CIO (Chief Information Officer).

Adi Katz is the head of the Industrial and Management Department (IE&M) in Sami Shamoon College of Engineering (SCE) in Ashdod, Israel and the head of the Information Systems track in the department. Katz is also the head of YOUsability, the Usability Research Center, for developing and testing technological artifacts. Katz specializes in the areas of human-computer interaction (HCI), computer-mediated communication (CMC), and conceptual modeling. Her main research interests include cognitive and affective aspects of user interface (UI) design, visualization, and conceptual database modeling. Katz has published papers in journals such as Organizational Science and Interacting with Computers (IwC). Her paper in IwC, entitled "What is Beautiful is Usable" (co-authored with N. Tractinsky and D. Ikar), has been cited over 1,930 times. Her teaching portfolio is broad, focusing on human-computer interaction, databases, and information and communication technologies (ICT). Her research in IS education focuses on difficulties encountered by novices in database conceptual modeling.