Using eye-tracking for explaining efficiency differences of media

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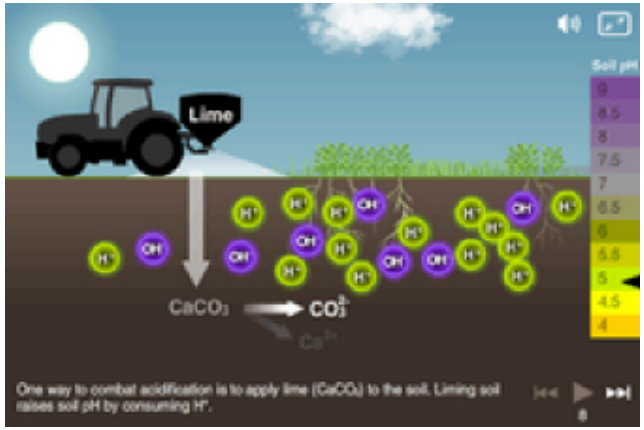
Study

Testing the efficiency of information extraction from animation versus text in a case study featuring a real world application



Soil Acidification

The pH of soil indicates the strength of acidity or alkalinity in the soil solution which bathes soil constituents, plant roots and soil micro-organisms. The more hydrogen ions (H^+) in the soil the more acidic it is. The more hydroxyl ions (OH^-) in the soil the more alkaline it is. While pH is measured on a scale of 1 to 14, most agricultural soils are found between the range 4 to 10 (when measured in water). For practical purposes, soil is neutral when pH is between 6 to 8, depending on plant requirements, and it is acidic when pH is less than 6 and alkaline when it is greater than 8. A pH of 9 denotes a very strongly alkaline soil, and a pH of 4 denotes a very strongly acidic soil.

Agriculture can change the pH of soil. Ammonium-based fertilisers, urea or the urea from the urine of animals can acidify the soil in the longer-term by producing ammonium (NH_4^+). The transformation of ammonium (NH_4^+) to nitrite (NO_2^-) to nitrate (NO_3^-) releases three hydrogen ions (H^+) into the soil. The presence of a greater number of H^+ ions than OH^- ions causes the soil pH to drop.

Nitrate leaching, where NO_3^- moves below the root zone and cannot be used by plants is a significant source of agricultural acidification. Furthermore if the ammonium (NH_4^+) living in nodules on legume roots is not all used up by the crop or pasture the soil can become more acidic.

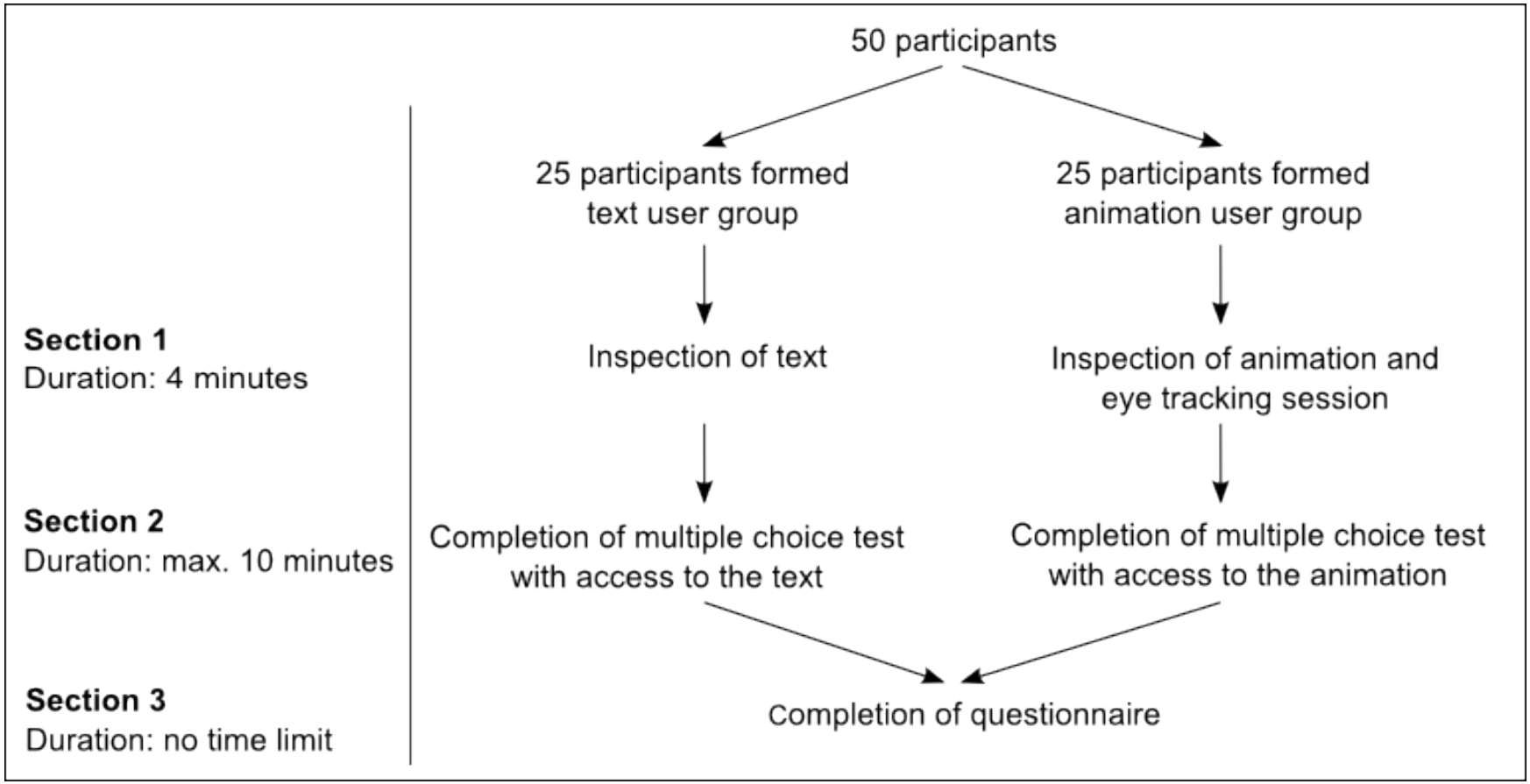
Agriculture can also accelerate acidification by removing alkaline products such as wool, milk, cereal grain, legumes and hay. The reverse is also true, where the introduction of manure, decaying animals, silage and stockfeeds can add alkalinity back into the soil and therefore increase soil pH.

Plant production can be constraint on strongly acid soils by aluminium toxicity and manganese toxicity. Both are more soluble at low pH, for example, aluminium dissolves into the soil solution as Al^{3+} that is taken up by the plant causing root deformation and stunted plant growth.

If a soil continues to acidify until it becomes very strongly acidic, biological activity, soil structure and nutrient toxicity and deficiency can become significant challenges to productive agriculture.

One way to combat acidification is to apply lime ($CaCO_3$) to the soil. The breakdown of lime ($CaCO_3$) in the soil produces oxygen (O_2^-) and water (H_2O). This reaction consumes H^+ ions and inreases soil pH.

Experiment design



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Research Questions

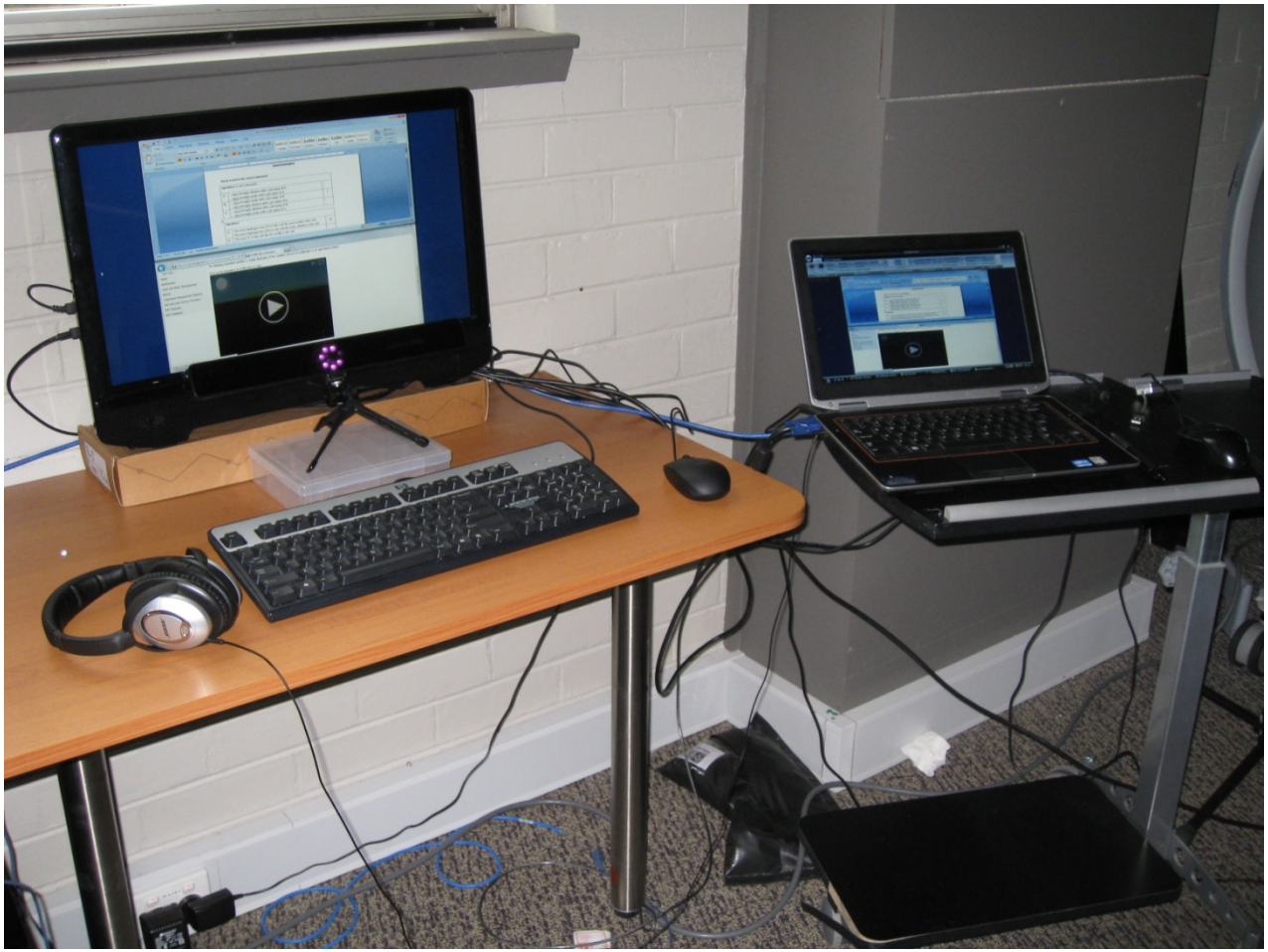
- RQ 1:

  Is it more efficient to extract information from the animation or from the text?

- RQ 2:

  Do the eye movement measurements recorded during the inspection of the animation underpin in any way the performance measurements of RQ1?

Equipment



Coordination of multiple devices required

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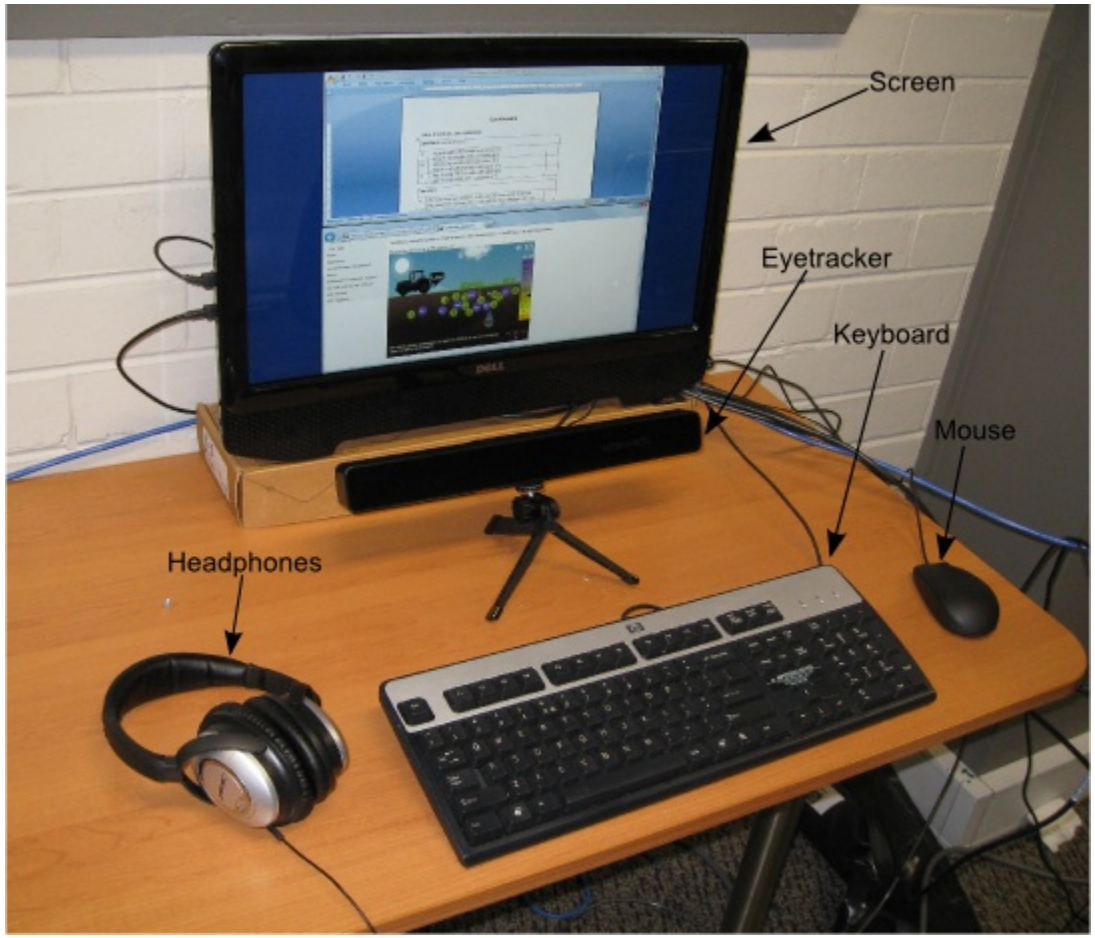
Experimental hardware set-up



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Mirametrix S2 Eye-tracking system

- Tripod stand
- System software available at www.mirametrix.com
- Separate purchase of data analysis software → code writing necessary

Technical Specifications

- Accuracy: <1° of visual angle
- Head Motion: 25x11x30 cm (Width x Height x Depth)
- Data Rate: 60 Hz
- Binocular Tracking
- Tracking Type: Bright Pupil
- Software based, source code included

Mirametrix S2 Eye-tracking system

Recommended System Configuration

- Windows XP SP2, Vista or Windows 7
- 1 GB of RAM
- Intel 2.0 GHz or greater (Dual core highly recommended)
- 15 – 22” LCD Monitor
- Available powered USB 2.0 port

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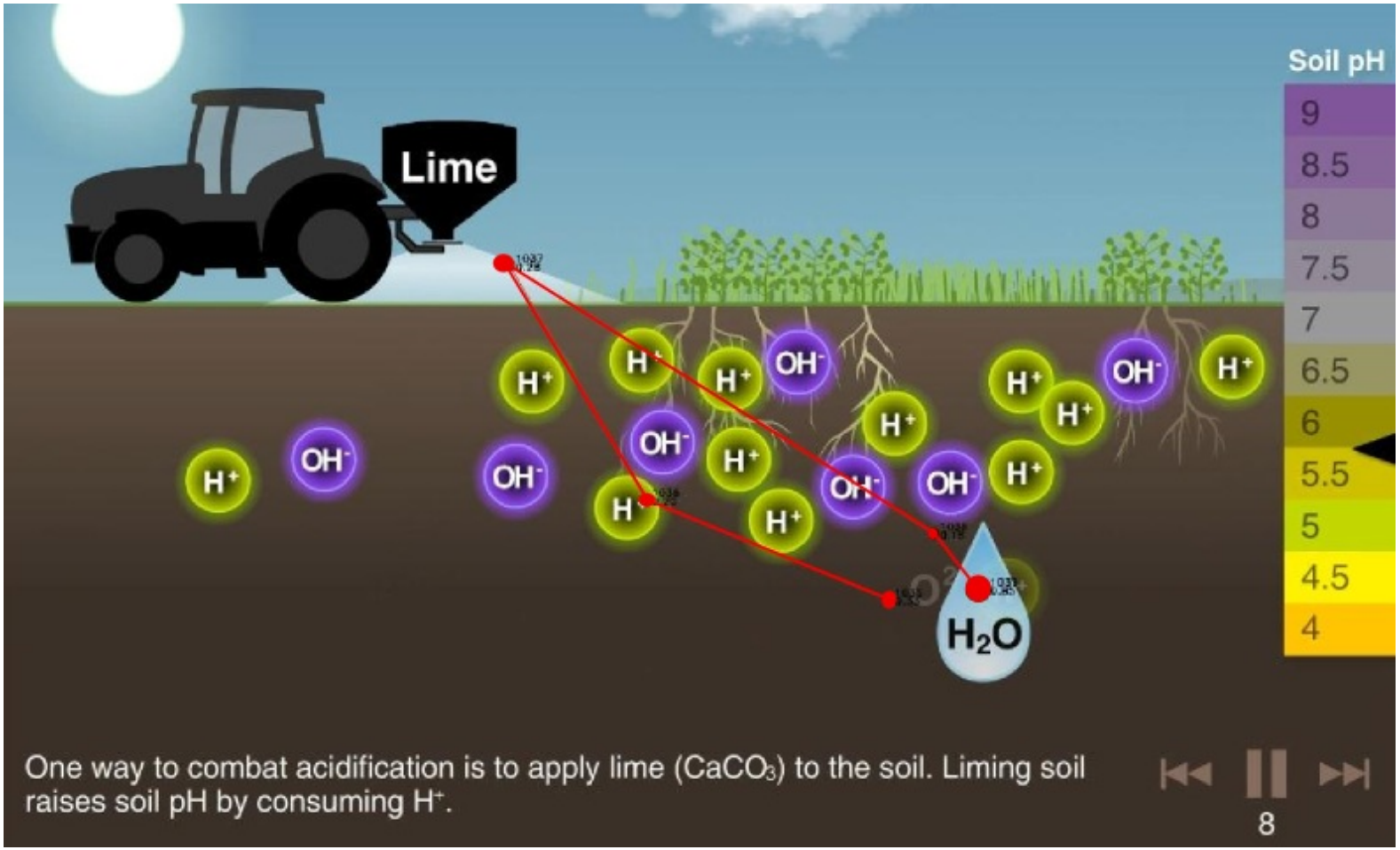
Section 1: Eye-tracking session during animation inspection



Example of a participant showing fixations and saccades

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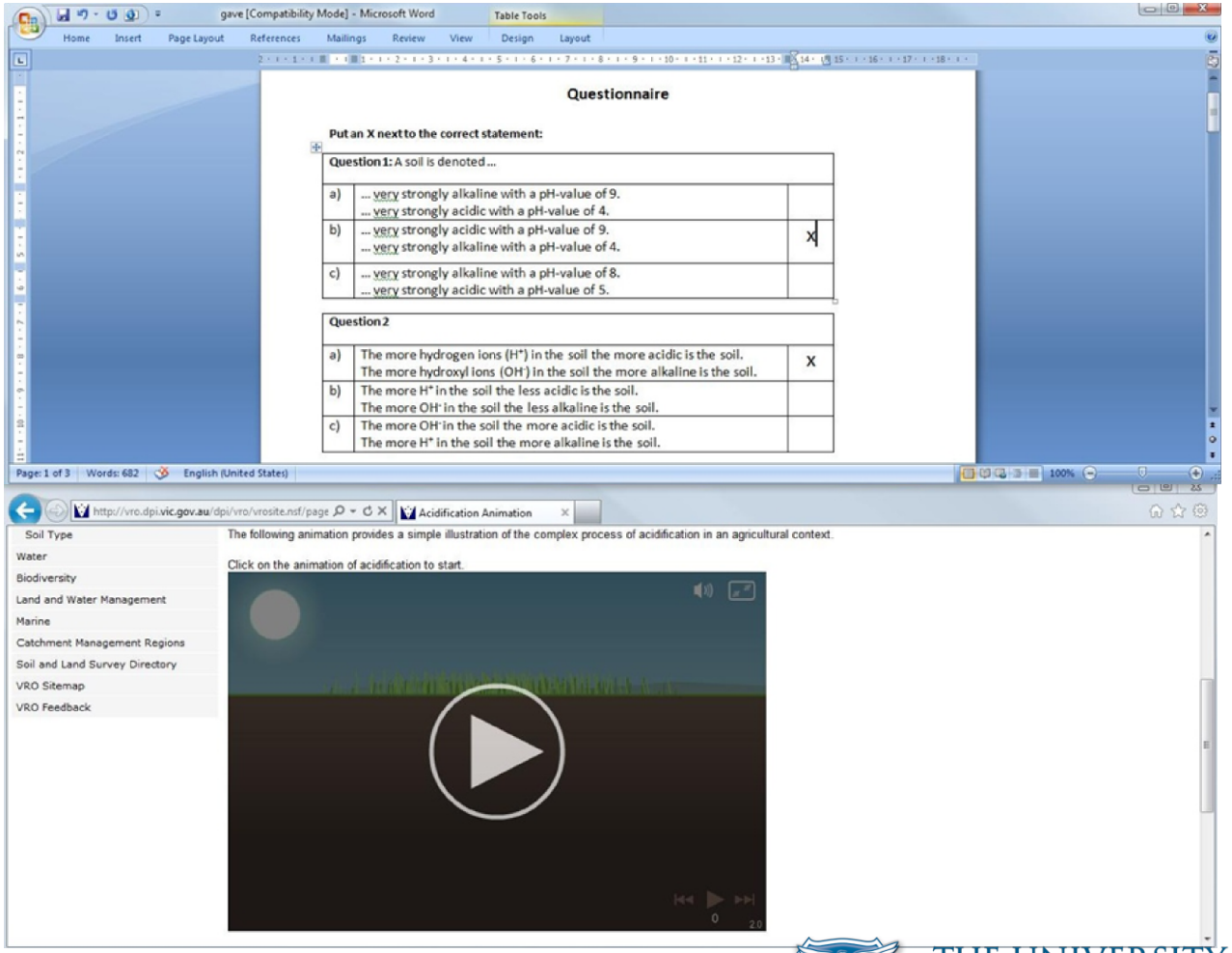
Section 2: screen display of animation user group

Multiple choice test

Animation



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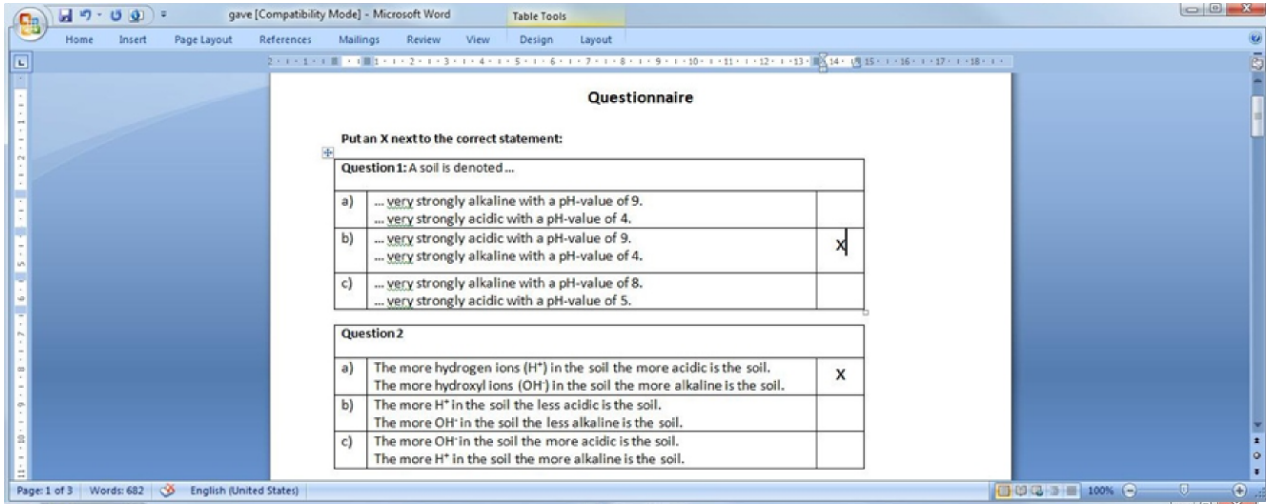
Section 2: screen display of text user group

Multiple choice test

Text



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Measurements 1

- *RQ 1:*

  Is it more efficient to extract information from the animation or from the text?

  -number of correct answers in the multiple choice test

  -required time to complete the multiple choice test

  -answers on the difficulty of extracting information from the stimulus (section 3: questionnaire)

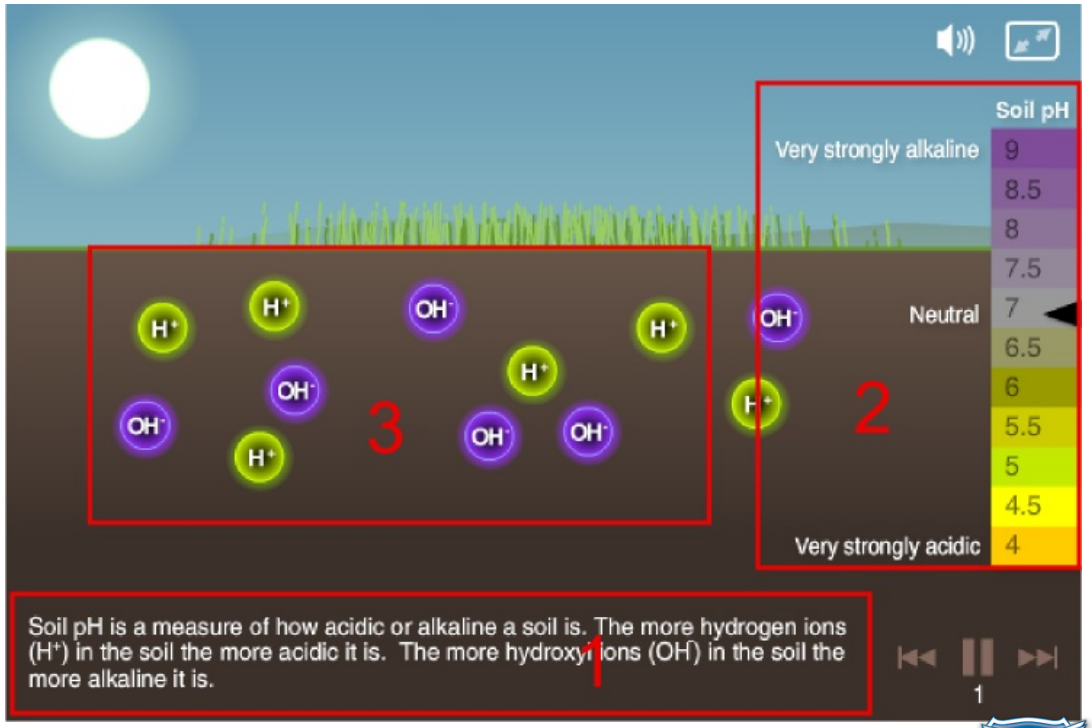
Measurements 2

- *RQ 2:*
  Do the eye movement measurements recorded during the inspection of the animation underpin in any way the performance measurements of RQ1?

  Metric:
  Mean Fixation Duration (MFD), on specifically defined Areas Of Interest (AOI) within each scene of the animation (Schmidt-Weigand et al. 2010).

Example: Areas of Interest (AOI)

- For each scene of the animation the ‚relevant' AOIs (i.e. containing the information to answer the questions correctly) have been defined



Red boxes: relevant AOIs

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Interpretation eye-tracking data

- based on Jacob and Karn (2003):

  -the longer the MFD, the more effort participants have exerted to extract information from the AOI.

- Relation to RQ2:

  -correlation between time for completing the multiple choice test and the MFD on the relevant AOIs

  -If the MFD on the relevant AOIs were relatively high: animation users may have been delayed by difficulties encountered in decoding the information.

Results

Table 1 Summary of the data collected during the experiment

	Animation	Text
Number of participants	25	25
Mean participants' age	24.1	20.4
Multiple choice test		
Mean number of correct answers	8.52	8.60
Required time (min)	06:17	05:38
Questionnaire		
Prior knowledge about chemical processes in soils (1 = no knowledge, 6 = high knowledge)	2.6	2.8
Participants rating information extraction 'very easy'	4	2
Participants rating information extraction 'easy'	17	15
Participants rating information extraction 'difficult'	3	5
Participants rating information extraction 'very difficult'	0	1

Results: multiple choice test

Text users …

… have achieved a slightly higher score of correct answers (Ø number of correct answers 8.6 vs. 8.52)

… required less time (~40 sec) to complete the MC test

… but more animation users stated the extraction of information 'very easy' and 'easy'

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Results: eye-tracking

- the MFDs for relevant AOIs are not higher than for the non-relevant AOIs in any case

→animation users have not been delayed due to difficulties in extracting the required information, but rather may have been distracted by (or attracted to) the other elements that are displayed on the studied scenes

Limitations

- eye-tracking data is from section 1 and not section 2 (screen division in section 2 restricted the size of the animation and made eye-tracking difficult)

- definition of ‚relevant' and ‚not-relevant' AOIs is critical since (all) animation components together should provide the information

- experiment required high coordination (two groups, time conditions, multiple experiment sections, multiple sources and devices, etc.)

Limitations

- Entry level eye-tracking equipment utilised
- less accurate (calibration) and sophisticated than more expensive ones
- data analysis software not included → time-consuming code writing necessary

Open questions

- If not the 'relevant' AOIs have delayed the participants which other animation elements have the participants been distracted by (or attracted to)?

- Are the used metrics and interpretations appropriate?

- What other approaches (methods, experiment designs) may be undertaken to achieve more reliable results?

Open questions

- Would the results of been different if soil scientists (experts where tested, rather than students (novices)? (Mayer, 2010)

- How do account for different memory performance from participants?

Further research

- better understand the potential contribution of eye-tracking for explaining efficiency differences of different communication media.

- Better understand the *effect* versus *affect* – a lot of interest in animations from end users.

Bibliography

- Hegarty M, Kriz S (2008) Effects of knowledge and spatial ability on learning from animation. In: Learning with animation: Research implications for design (2008) Editors: Lowe R, Schnotz W, Cambridge University Press, New York 3-29
- Jacob RJK, Karn KS (2003) Eye tracking in human-computer interaction and usability research: ready to deliver the promises. In: The Mind's Eye: Cognitive and Applied Aspects of Eye Movement Research (2003) Editors: Hyona J, Radach R, Deubel H, Elsevier Science, Amsterdam 573-605
- Schmidt-Weigand F, Kohnert A, Glowalla U (2010) A closer look at split visual attention in system- and self-paced instruction in multimedia learning. Learning and Instruction 20:100-110
- Tversky B, Bauer J, Betrancourt M (2002) Animation: can it facilitate? International Journal of Human-Computer Studies *57*(4):247-262
- http://vro.dpi.vic.gov.au/dpi/vro/vrosite.nsf/pages/soilhealth_acidification