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**Citation:** Reimers, S. (2013). Developments in information technology and their implications for psychological research: Disruptive or diffusive change?. Learning at City Journal, 3(1), pp. 45-53.

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**Developments in information technology and their implications for psychological research: Disruptive or diffusive change?**  
**Dr Stian Reimers, Senior Lecturer, Department of Psychology**

**Abstract**

The notion of technology-induced disruptive change has generally been applied within academia to teaching and learning. Less explored is the disruption that occurs to research as mainstream technology develops. This article examines the effects of technological change on research in psychology, in particular focussing on the development of web-based empirical research procedures over the past 15 years or so. I discuss the history, challenges and potential of these developments, and put forward some qualified suggestions for some of the future directions that technology will allow research in psychology to take.

**Keywords:** Psychology, research, web, internet, methodology, computer, experiment.

The notion of disruptive change in academia (Christiansen, 1997) has most commonly been applied to the learning and teaching experience, highlighting how the development of the world wide web, email, virtual learning environments, social media, and MOOCs, among other things, has challenged and disrupted existing teaching norms, and led in some cases to substantial shifts in teaching practices. However, technology has also led to disruption and transformation in research. The development of specialist research technologies has transformed scientific research, from MRI in neuroimaging to DNA sequencing in biology, to one-off projects like the Large Hadron Collider in particle physics, new technology has rendered older techniques – and often findings – very quickly obsolete.

However, disruptive change does not just come with the development of new research technologies. Just as in teaching and learning, it has also come as an unintended consequence of more general technological innovation. Some of the largest challenges for research have come as a result of the development of the World Wide Web. The influence has been widespread. As Sumner (2012) has noted, the upcoming generation of researchers use the web to access and manage information, collaborate across continents, and disseminate and promote their research using social networks. It has also facilitated the peer review process, and led to new ways of publishing research. For example, the journal PLoS ONE publishes online, and has a review process that evaluates basic experimental rigour, but explicitly rejects importance or impact as criteria for acceptance or rejection. Instead, it allows readers to submit comments that are available along with citation and social media metrics (like blog comments and facebook 'shares'), which lets readers decide on, and discuss, the article's importance.

In my field of experimental psychology, all of these factors are influencing research. There is discussion about open-access publication (and the ethics of publishing behind a paywall), which has led to the development of new open access journals (like Judgment and Decision Making; [journal.sjdm.org/](http://journal.sjdm.org/)), with international collaboration the norm, and some excellent examples of brain science related blogs and related twitter accounts (such as mindhacks.com and [blogs.discovermagazine.com/neuroskeptic/](http://blogs.discovermagazine.com/neuroskeptic/)) help disseminate findings and spark (often quite heated) discussion.

However, unlike most other experimental sciences, psychology has seen the influence of general ICT development directly on the practice of empirical data collection, rather than on the peripheral, though important, research activities of reading existing literature and organising and sharing knowledge. In the past 15 years, psychological research has transformed from being an almost exclusively lab- or field-based discipline, in which participants generally meet the experimenter and complete an experiment in a university psychology lab, to one in which a significant amount of experimentation is conducted online. This has had and is having disruptive influences on research and its evaluation, and has the potential to cause significant disruption in the future.

## **A history of web-based research in psychology**

### *The pioneers (1995-2000)*

The first psychology experiments were run online in around 1995 (Musch & Reips, 2000), at McGill University, Canada, and Darmstadt, Germany. Arguably, these may not count as proper experiments, as they seemed to be used more as demonstrations to accompany teaching classes. Around the same time, a number of surveys also appeared online, collecting data but not experiments in the sense of manipulating independent variables between or within subjects.

Musch and Reips (2000) argue that the first experiment might be one conducted by Krantz, Ballard and Scher (1997; see Musch & Reips, 2000). It appears to be the first true experiment run on the web to be published in a peer-reviewed psychology journal.

From then, a number of testing sites sprang up. These were mainly in North America and continental Europe. In the UK there was only limited use of web-based research before the turn of the millennium, with one notable example being a psycholinguistics laboratory for a Scottish research group, which appears to be associated with the Universities of Glasgow and Edinburgh (see, e.g. Cohn, 2011) set up in September 1998.

In terms of design and implementation, most early studies were fairly simple, using HTML forms to capture data from participants, basic dynamic page construction (using, e.g., cgi), and often restricting stimuli to written scenarios or choices. For example, Birnbaum (2000) gave participants a series of choices involving risky decisions (of the form “Would you rather have a 50% chance of \$10 or \$5 for sure”). A small number of studies used images, and a very few also used audio stimuli (Musch & Reips, 2000), but the vast majority stuck to simple text-based designs, not least because of concerns about presentational consistency. Sticking to these techniques meant that research focussed on areas that could use them, for example, avoiding work on perception, where visual or auditory stimuli would be required, or measures requiring the timing of responses, for which no evidence of reliability was available.

### *Developing techniques and practices (2000-2010)*

The decade at the start of the 21<sup>st</sup> century witnessed two key trends. First, using the web became mainstream. In December 1999, around 250 million people were online globally, 4% of the population (Internet World Stats, 2012). By the end of 2010, the number was 2 billion, with over 80% of people in the UK online. Second, as hardware performance increased, so new software was developed to enhance or capitalise on the web experience. Client-side plugins that run on the user’s machine such as Java and Macromedia (now Adobe) Flash

penetrated the internet-using market, and tools such as JavaScript became increasingly sophisticated and powerful.

These developments had clear effects on psychological research. The increase in the number of people online made participant recruitment easier and the sample population more representative of the general population. When I ran my first web-based experiments in 2003, when asking people their age, I had a single category for 'over 65', and virtually nobody chose it. When I ran a similar experiment in 2008, a significant proportion of respondents chose it, and I now get participants to give their precise age up to 100 years old. This had made it easier to examine cognitive ageing across the whole lifespan rather than just among the younger people who tended to use the web in the past. The sheer number of people online made it possible to run experiments with vast numbers of participants, which could examine effects that would otherwise be impossible to look at in smaller samples. In 2004-2005 I ran what was, at the time, one of the largest psychology experiments ever conducted, in conjunction with the BBC, with over 250,000 participants completing the 40-minute experiment (Reimers, 2007).

Tools like Flash and Java were used by psychologists to conduct research. This is typical of disruptive innovation, appropriating a technology designed for something else (showing animations) to serve an aim for which it was not designed (running experiments and measuring responses). Engstrom (1987) notes that tools have more uses than those envisaged by their inventors, and this is very much an example of that. I published one of the earliest papers reporting response time measures collected over the web (Reimers & Maylor, 2005), examining cognitive decline with age, and quantifying increasingly larger switch costs among older participants. As there were no data about Flash's reliability across different hardware, I used a within-subject baseline, so reaction times for a complex task were compared with those for a simple task, largely controlling for any variability that might be present. Again, this could not practicably have been done without web-based research. I later followed up by assessing the reliability of web-based reaction time measures (Reimers & Stewart, 2007), highlighting the strengths and limitations of the area.

In parallel with direct web-based experiments, other researchers started using material on the web as data, examining, for example, the content of web forums, or the nature of public interactions on forums.

As is often the case with disruptive change, the institutions and gatekeepers appear to have been relatively slow on the uptake. The American Psychological Association published a summary of opportunities and challenges with web-based research in 2004 (Kraut et al., 2004), and the British Psychological Society produced a set of guidelines in 2007 (British Psychological Society, 2007), although others had highlighted potential ethical issues long before (e.g., Binik, Mah & Kiesler, 1999). Both publications commented on the issues of informed consent in web-based studies, the question of whether online behaviour should be considered public or private, as well as issues of data reliability. These are discussed further below.

#### *Research 2.0 (2010-Present)*

*Social networks.* Although social networks had been developed several years before, it was largely from 2010 the psychologists started examining them. Research has examined how

people portray themselves on social networks (e.g., Back et al., 2010), the importance of social networks in reducing risky behaviours (Rice et al., 2010), and even the extent to which facebook information can predict potential employability (Kluemper & Rosen, 2009).

*Crowdsourcing.* The use of crowdsourcing – the recruitment of large numbers of people to assist with a labour-intensive task – has developed rapidly over the past 5 years. At the forefront has been Amazon's Mechanical Turk ([www.mturk.com](http://www.mturk.com)). Here, researchers can offer small amounts of payment for participants' completion of short psychology experiments. Results have generally be very similar to those found in traditional lab-based experiments (see, e.g. Paolacci, Chandler, & Ipeirotis, 2010; Simons & Chabris, 2012 for examples). Mason and Suri's (2012) overview of using MTurk for psychological research notes that the hourly rate of pay for MTurk workers average \$4.80, but could be as low as \$1.71 and still gather reliable data. Similarly, short tasks could be set up to pay just \$0.01, and although participant recruitment took longer than offering \$0.03 or \$0.05, participants did complete the task. There are of course ethical issues to this very low payment, some of which are covered by Mason and Suri (2012).

#### *Future directions*

Internet-based research is still in a state of flux, with new capabilities coming online every year. Although futurology is a risky activity, I think there are two exciting ways in which research will be disrupted by new technology in the next few years. The first is the increasing ubiquity of smartphones. Although I have written papers on the use of mobile phones for data collection (Reimers & Stewart, 2008; 2009), a much more expansive overview has recently been given by Miller (2012). He focuses on both the hardware available in smartphones that could provide data, in particular GPS and movement measurement using the phone's accelerometers, as well as the capacity for testing people in different, real-world environments. This has the potential for gathering novel, and more ecologically valid, data.

The second major development that I think will affect future research will be the networking of games consoles, allowing new input devices to be used online. For example, the Nintendo Wii uses a controller with three-axis accelerometer, and a balance board for measuring centre of gravity. It is already possible to use the Wii controller to interact with web pages shown through the Wii's browser, but it is currently rather cumbersome (Reimers & Stewart, in preparation). However, an increasing emphasis on multiplayer games and real-time networking over the internet means that by the end of the decade it is likely that it will become much easier to record data from console input devices over the internet. Being able to gather data from, for example, a next generation version of the Xbox Kinect, which measures 3D movement via a camera, or even physiological responses like pulse and blood oxygenation via a Wii Vitality Sensor or Ubisoft Innergy Sensor, would give psychologists remote access to an exciting range of new data. It would also offer the potential of running experiments that would be difficult to run now even in a dedicated laboratory.

#### **Advantages and disadvantages of web-based research**

Clear advantages of web-based research are related to the sample population. First, it is possible to recruit large numbers of participants at minimal cost and effort. Second, it allows researchers to recruit a much more representative sample of participants, relative to the psychology undergraduates who tend to take part in lab-based experiments. Finally, it may reduce experimenter bias or demand effects in experiments, where participants attempt to

act in a way they think the experimenter wants them to act, or that the experimenter gives subtle cues about how the participant should act.

There are of course potential downsides. Data reliability is potentially an issue, with participants having less social pressure to take a test seriously. Dishonesty about demographics, and multiple submissions from a single user are other potential concerns.

Arguably, making research easier has the potential to encourage speculative or poorly-designed experiment “just to see”, and thus risks inflating the probability of finding false positive results. It becomes economically and practically feasible to run many experiments, and only publish those with significant findings. As replication is becoming an important issue in psychological research (see, e.g., Pashler & Wagenmakers, 2012), this is potentially a problem. That said, the use of the web has also helped combat some of these issues, with sites such as Psych File Drawer documenting replication attempts for existing studies, which would not normally be accepted in journals (<http://www.psychfiledrawer.org/>).

Finally, there are ethical differences between web-based and lab-based experiments. The absence of a reassuring experimenter may lead participants to feel uneasy or confused at the end of an experiment, and there is no opportunity to answer any questions a participant might have. Participants cannot easily be screened for age or mental health. On the other hand, the lack of social pressure to continue even when feeling uncomfortable (it is easier to close a browser window than to walk out of an experimental lab) makes potentially for a more ethically acceptable experiment.

### **The new researcher**

The psychology researcher in this new world requires a different set of skills from those of previous generations. Programming skills are increasingly important, as there is very limited user-friendly psychology testing software available for online research. Instead, researchers need to learn ActionScript, Java, JavaScript, along with HTML, to set up experiments, and need to understand the basics of how servers and databases work.

Relatedly, technical analytical skills are becoming increasingly important to handle the increasingly large datasets that online research is producing. The BBC dataset (Reimers, 2007) collected in 2004-2005 could not be opened by the version of Microsoft Excel that was available at the time, as it was too large, and even simple analyses using the statistical tool SPSS could be very time consuming. With other previously unwieldy datasets (such as the British Household Panel Survey) being made available electronically, programming languages such as R are becoming increasingly important for data cleaning and analysis.

Finally, the geography and demography of research is opened up much more. In the past, researchers have had to have access to funds to pay those participants, have access to facilities such as testing rooms with computers, and a significant amount of time to spend testing those participants. This has meant that most research has been conducted in large, well-funded universities in the developed world. With the possibility of running experiments online, paying participants \$0.10 for a two-minute study, programming and analysing the data using open source software, anyone with a hundred dollars and a laptop could – in principle at least – run an experiment that could give important insights into psychological processes. Similarly, the public availability of ‘big data’, means that testing is increasingly optional – it is becoming more the case that people with good analytical skills and

interesting hypotheses to test are able to thrive, rather than those with the most financial resources.

### **Disruptive or diffusive change?**

I hope I have made the case that web-based research has radically changed the way in which psychological research is done. The question arises: Is it really disruptive change?

In some way it has been. Reviewers, whatever their interests, have had to consider the validity of new ways of conducting research, reconsidering issues of design, ethics and analysis. For example, as web-based research tends to lead to noisier data, rules of thumb about effect sizes may have to be reconsidered. In the early 2000s, some reviewers would recommend rejection of a paper that used a web-based methodology. A number of early studies explicitly comparing web and lab results and finding minimal differences (see Krantz & Dalal, 2000, for an example) eventually led to wider acceptance of web-based research.

In other ways there has not been wholesale change. Most current web-based research uses procedures that are identical to those used in the lab, rather than radically redesigning a research approach to best use the technologies and potential of the web. This state of things perhaps mirrors the way in which new learning technologies have tended to copy existing practices rather than radically overhaul the way in which teaching and learning happen (e.g., Fry & Love, 2011).

It is also of course, quite possible to conduct research in psychology without running experiments online, and there are often very good reasons for running experiments in the lab. That said, many researchers appear to have an attitude that they will continue running lab-based experiments even in those cases where web-based approaches offer significant advantages, because it is the way they have always done things or because they do not feel confident with the web-based setup. As such, there are aspects of a diffusion of innovation idea (see, e.g., Rogers, 1976), in which the innovators and early adopters have converted to – at least in part – using web-based technologies, but with many other researchers yet to pick up the technology. It will be interesting to see how it develops.

*This article was originally submitted as coursework for the Information & Communication Technology in Higher Education module on the MA in Academic Practice*

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