New Consumer Research Technology for Food Behaviour

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The last decade has witnessed an explosion of new consumer behaviour research technology, and new methods are published almost monthly.

consumer research technology | food choice | validity of consumer research methods

1. Introduction

In recent, years many new technological research methods have been proposed, tested, and published that enable the study of consumer food behaviour. The developments follow each other very rapidly, and by now, a very diverse palette of research methods has become available for consumer researchers to choose from. On the one hand, this results in new and promising possibilities to study consumer food behaviour; on the other hand, it may also result in unclarity for researchers. It can be difficult to decide which methods are available for specific research questions and how useful and valid they are. An overview of a wide range of methodologies is needed. For food consumer scientists specifically, it is of interest to find out whether new methods are applicable in their area and if they provide valid measurement results.

1.1. Input and Output Technologies

The current study adds to the literature by providing an overview of novel technologies in the area of food consumer behaviour. Researchers broadly differentiate between input and output technologies. Some technologies are used to bring the consumer into a certain situation in order to create a mind-set as close to real life as possible. Different contexts, operating at the input side of a study, are typically the independent variables of a study. Although researchers acknowledge the presence of different types of input, as noted, for example, by the recent so-called EPI-cube (Embodiment-Presence-Interactivity, [1]), they will not further differentiate between them.

Other new technologies are used to measure consumer related variables in order to get a grip on consumer behaviour or responses; these work at the output side of a study and typically are the dependent variables of a study.

Providing information to a consumer in an experiment (or to a respondent in a survey) can happen in many ways. The input side of consumer research consists of the experimental situation, which can include the screen of an online survey, the instruction by an experimenter, the physical surrounding during a measurement or any context provided by means of VR and related technologies.

At the output side of consumer behaviour, several types of new technologies can be used to measure behavioural outcomes. Here, researchers distinguish three types of methods aimed at collecting data on a neuroscience, a psychological, or a behavioural level.

Neuroscientific measurements, are measurements related to neural activity. They often refer to neurophysiological measurement, be they CNS (Central Nervous System) or ANS (Autonomic Nervous System) based. CNS-based measurements often employ such technologies as EEG, fMRI, or MEG, and they often point at some form of cognitive processing. Other psychophysiological measurements, i.e., of a wide range of ANS functions, often indicate the execution of tasks.

Psychological measurements inquire about psychological traits or states of a human subject—in the case, a ‘consumer’. Despite the seemingly broad range of methods that could fall under this heading, researchers define them as measurements of mental phenomena. Self-reported, past, or prospected behaviour is also considered a psychological measurement.

Behavioural measurements refer to the observable behaviour of a consumer. Any movement that is somehow monitored can constitute a ‘behavioural measurement’. Typically, these are motor measurements such as gait, movement, agitation, but hand movement, eye-movement, face movement, or chewing behaviour also fall under this heading. Response time measurements are also an example of a behavioural measurement.

One recent interesting innovation exists in voice assistants. Typically, one may think of voice assisted device operation (car navigation, phone number calling, (very) smart TV programming, [2]). One can also think of types of smart devices, such as Google Assistant or Siri. These devices can be used for consumer research by asking questions or giving instructions to consumers to operate their devices. At the same time, these smart devices may collect data in the form of the responses consumers give to their instructions or questions. Ethical problems obviously lurk, as it is not always clear if a consumer wants his/her voice commands and responses to be recorded for subsequent analysis, even if anonymously.

1.2. Implicit and Explicit Methodology

Explicit consumer research methods are those methods that require some form of answering from consumers, often using conscious reflection. Consumers have to make explicit what they mean, why they act as they do, why they make some choice, etc. Hereby, they are conscious of what they are answering, and they may ponder their answer before they give it. In contrast, *implicit* methods do not require consumers to do this. The implicitness, here, refers to the fact that information concerning consumer behaviour is inferred from a measurement without the consumer knowingly having control over the outcome (cf. [3][4]). As an example, the amount eaten and the speed with which food is consumed can be seen as implicit measures of acceptance of the food.

One may be tempted to think that implicit methods always require consumers being unaware of the measurement, but this is not true. It is possible to have consumers explicitly report on some matters but without the research question being addressed in this matter. The answers of the consumers can next be studied to provide evidence of their ideas, opinions, or attitudes concerning the matter. This type of measurement is implicit, although consumers are to explicitly answer some questions. In this case, the implicitness of a consumer measurement concerns the consumer being unaware of the underlying research question, rather than in the way consumers are to provide data (which appears explicit).

2. Input Side: Context Providing Technologies

Food products are seldom consumed in isolation. Instead, foods are typically consumed in specific consumption situations, such as at home, in a restaurant, or at a canteen. These situations tend to shape the food experiences. Consequently, food preferences measured in a sensory laboratory may be different from preferences for the same foods measured in a real-life situation, as demonstrated by numerous studies. Many of these studies report higher preference ratings in real-world situations [5] or differences between several contexts [6][7], even though there are also some studies that report no difference [8].

Testing consumers in real-life consumption situations is often difficult because these situations tend to be noisy and offer little control over conditions, which may have unwanted effects on the measurements. Instead, there is a growing trend to recreate consumption contexts in the laboratory. Using so-called ‘immersive technologies’, these recreated contexts offer a compromise between real-life consumer experiences and tightly controlled laboratory conditions. ‘Immersion’ is a term used for what is thought to happen to consumers in a research situation where they are provided with a situational context that totally captures their attention—ideally to the point that they forget that they are in an experimental context. As advantages of ‘immersive technologies’, some have been mentioned:

- overcoming the ‘respondent burden’ (the degree to which a consumer finds participation difficult, time consuming, or emotionally stressful [9],
- increasing some statistical quality (validity, reliability, power) of the collected data [10],
- adding control to an experimental situation, while keeping the situation ‘ecological’,
- adding context to (online) surveys to enable more truthful (and hence valid) answers or to increase commitment from respondents.

In a way, telling a good story to a consumer, in an otherwise quiet testing room, can also be seen as an immersive ‘technology’. Reading a story from a paper or listening to a story told is so low-tech that researchers will not cover this in more detail here [11] (p. 30 on ‘Story Telling’ and p. 31 on ‘Sketchy descriptions’). In short, anything to have the subject mentally ‘leave’ the testing surrounding and enter the realm of their imagination can be seen as an ‘immersive’ technology. Short, specialised surveys have been developed to probe how deep consumers felt ‘immersed’ while being in such a situation [10].

In the below, researchers will introduce some recent (input) context providing technologies, ordered from a relatively low level of ‘reality’ (or ‘immersiveness’) to a high level.

2.1. Tabletop Technology: A Tablet Computer as an Expensive Coaster

To provide consumers with a special eating context while dining, tablet computers have been used. They can provide a special context to the food, and it’s feasible to apply them in this manner in food testing (**Figure 1**, left panel). However, other ways may be possible that are less cumbersome or expensive. Other technology, e.g., sound, has been provided with food in a similar vein (**Figure 1**, right panel).

Figure 1. (**Left panel**): a tablet computer as a plate to hold your food. (**Right panel**): sound provision during eating (from [12], p. 316 and 329, resp.).

2.2. Virtualised Food Products

Using photogrammetry, a food product is totally visually digitalised and digitally recreated. The recreation may follow a (factorial) design, systematically varying aspects of the food product (e.g., its size, shape, colour, surface roughness, etc.), to be presented to consumers. The consumers next assess sensory properties, of course restricted to visual aspects, but they could assess expectations of other aspects, as texture or flavour. Gouton et al. [13] present an application using chocolate chip cookies and a comparison of simulated cookies with real cookies. Some differences were found, which Gouton et al. [13] suggest may depend on specific photogrammetric software settings.

2.3. VR Technology

A plethora of VR-related technologies has seen the light in the last decade. VR-glasses have been around for a while, and they can now be obtained against relative low costs. Tools and devices exist where one can insert a cell phone in a device (**Figure 2**), and dedicated apps on the cell phone will assure a VR-presentation when wearing the device. Cardboard -fold your own- versions exist for under €1. These lend themselves for being sent to large groups of consumers, for in home, online survey testing, providing context through dedicated apps. Dynamic context, the typical VR-experience where one can virtually move around inside a surrounding, can be provided through these means. Many tools include integrated sound and, often, spatial sound effects.

Figure 2. (**Left panel**): VR glasses, wherein one can slide a cell phone; (**Middle panel**) (reprinted with permission from OVR technology (Copyright OVR technology)) and (**Right panel**) (reprinted with permission from Takuji Narumi (Copyright Takuji Narumi)): a VR system enabling olfactory stimulation.

Taufik, Kunz, and Onwezen [14] conclude that VR-provided contexts often lead to measurement results comparable to their real life counterparts. In addition, they conclude that the technology also seems promising to lead consumers to change their behaviour. Fang et al. [15] point out that VR methodology can also help reduce the hypothetical bias (the difference between a real experiment and an imagined one) by introducing a form of realism to the measurement situation.

Adding odour, relevant in a food context, to a virtual surrounding is more of a challenge. Several devices have been developed, but maybe some should be called contraptions instead (see **Figure 2**, rightmost panel). Advertisements exist, boasting about their ability to produce 1 ms short odour pulses and a time to switch between odours of 20 ms. When one realises that it may take some 300 ms, depending on many circumstances, for an odourant to reach olfactory receptors [16], such numbers look a bit over-the-top.

Other VR applications exist that use vibratory devices to simulate felt textures on the hand [17]. Straightforward applications in food related consumer science may not be in sight, or it must be the possibility to deliver vibratory stimulation in-mouth to simulate oral texture. Although technically feasible at this moment, it’s probably currently restricted to laboratory environments [18].

Bone conducting devices have been applied to record auditory and/or vibratory stimulation. In particular, in specific food related studies, where one may want to record the chewing sound as perceived by the chewer her/himself, and researchers know that chewing sound is, to a large extent, bone conducted sound [19][20]. They could also be used to provide food related auditory or vibratory stimulation, e.g., to adapt the sound perceived (vibrations felt) by consumers when chewing food (although they have not found papers in this area). A vibrating straw technology exists where no food is sucked through the straw, but a vibratory device can deliver the illusion of food streaming into the mouth [12].

Another technology is the development of ‘Sensory Reality pods’ (**Figure 3**). Inside something that is best described as a ‘phone booth’, a subject takes place, puts on VR-goggles, and can, from within the Pod, be stimulated with sound, smells, air flows, and heat radiation. It provides a multisensory immersive surrounding. Applications in food science may be a bit farfetched at the moment, but they are certainly feasible. At this moment, one person at a time can be immersed, but in theory, several pods can be used simultaneously, if only cost were no issue.

Figure 3. A subject sitting in a ‘Sensory Reality Pod’ (Reprinted with permission from SENSIKS. Copyright 2019 SENSIKS).

2.4. AR Technologies

In AR (Augmented Reality) parts of the real physical surrounding of a consumer is integrated into the virtual surrounding. VR knows limited application in eating research or other applications due to the fact that consumers cannot comfortably interact with a real food. Many VR devices do not allow smelling, eating or drinking, and will spoil the immersion. In AR the interaction is provided through integrating an object into the virtual surrounding. A fully natural interaction with ones surrounding, in particular with the (food) object, is still not possible. The interaction will likely still feel alienating.

In the development of packaging, AR applications are clearly envisionable, as they allow visual interaction of a consumer with a packaging. Coupling visual AR to a haptic vibratory device (providing manual package texture simulation), one can imagine that the interaction may reach a level close to reality.

2.5. (Serious) Gaming Applications

All above mentioned examples can also be used in gamification applications. A computer game aims to give a subject a lively sense of immersion by providing a virtual context. Reality is not implied in the type of context (the game can be about the weirdest of worlds), but it is provided by the interaction with the environment by the moving and handling virtual objects, reactions of other persons (or alien entities) in the game, etc. The original aim of computer games is entertainment, but a shift to consumer research applications is feasible. Gamification has also been applied to make surveys more engaging [21]. This is also an application area that can be of use to any type of consumer research.

Applications in (food) marketing exist in an application where visitors of an entertainment park can plan ahead their visit, enabling the park to optimally locate their services [22]. In particular, in the context of online purchasing, there may appear a future for such applications.

Giving smell or taste feedback in gaming applications has also been suggested [23], although this appears a farfetched application, as, at this moment, it is still at a distance from use in consumer research.

2.6. Wall Projections/CAVEs

The mentioned alienation in AR may result in it not yet being used much in food related applications or in typical consumer science applications where many consumers are tested. An alternative is the projection of a surrounding onto the walls of a room or in a 'CAVE'. A CAVE (a recursive acronym: Cave Automatic Virtual Environment) is a (small) room, where, onto the walls, an environment is projected, either by back projection (where the walls need to be translucent), normal projections by means of beamers, or using very large LCD-screens. WFBR (Wageningen Food and Biobased Research, one of the research institutes of Wageningen Research, part of WUR.) employs a CAVE-like projection room, where eight beamers can project images onto the walls of a normal room (**Figure 4**a). In addition to the visual projections, sounds can be played, and an odour dispersing unit is installed as well.

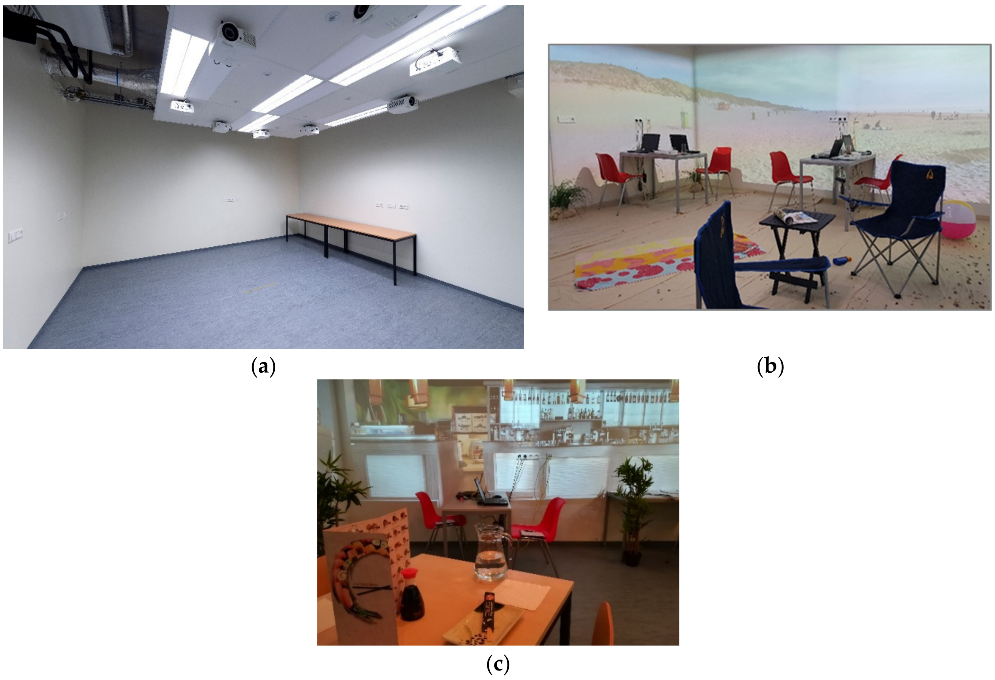


Figure 4. (**a**) WFBR ‘Experience room’. Lower: projections of a beach (**b**) and a sushi restaurant (**c**). Note that props are used in the room to add to the immersion. (Reprinted with permission from WFBR. Copyright 2019 WFBR).

Figure 4b shows the ‘Experience Room’ in action in a recent study where a beach environment was created. Note that props (towels, sand-coloured flooring) are used to add to the level of immersion in the simulated surrounding. The (c) panel of **Figure 4** shows a recreated sushi restaurant, including real tables with menus and some (plastic) plants to help increase the reality level of the simulation [24][25].

One can imagine that there is no limit to the possibilities of providing (near real) projections with sound and odour. Room temperature, air humidity, etc., could be added, provided the budget to develop the technology is high enough.

2.7. ‘Non-Virtual’ Reality

A special case is the immersion in a rebuilt environment, as was done by Holthuysen et al. [5], who rebuilt an airplane fuselage in a lab room, to test air catered food items, complete with airplane engine noise. It was immersion, but it is not the type of consumer technology researchers are addressing here.

3. Output Side: Measurement Technologies

In the sections below, several ways of collecting consumer related data are introduced, based on them collecting variables from neurophysiological, psychological, or behavioural origin. Researchers will present different methods in the three areas mentioned. Some will be mentioned only scantily, as they may be very new, hardly used, or are on the fringe of what they can see as promising new consumer measurement methods in the food area.

3.1. Neuro Scientific Measurement Technologies

Neuroscientific variables can be of an overwhelming complexity, in addition to them being plentiful. They have in common that they attempt to measure neuronal correlates of consumer behaviour relevant to the area at hand. Researchers will not introduce such techniques as EEG, fMRI, MEG, ANS-measurements in some detail, nor psychophysiology in general, but they list specific ways in which some of these technologies have recently been put to use to understand consumer food related behaviour. All these measurement techniques have that they require a connection to the human body in common. Although they do often not have to penetrate the skin or require otherwise invasive medical procedures, their impact on normal functioning mostly makes them listed as potentially invasive techniques. They will, thus, require some form of Ethical Clearance.

Innovation in food consumer neuro science may not only lie in developing new technology, in addition to the many existing methods that exist, but also in their combination. According to Niedziela and Ambroze [26], these methods should be used in addition to, not instead of, established food consumer methodology. It is useless to employ an expensive and complex measurement that is equivalent to liking, when a simple liking question may provide the same result.

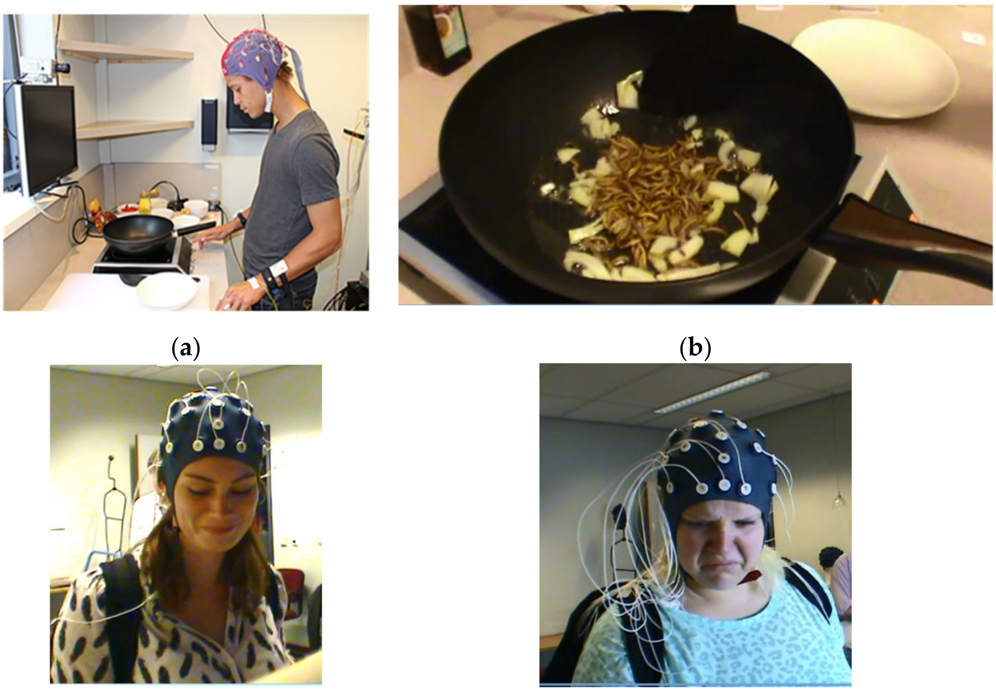
Another innovation is taking neuroscientific measurements outside the lab into the real world, which has to do with making the technology portable. EEG-caps have become, more-or-less, portable and allow for this. Ambient EEG measures may introduce additional noise, possibly rendering measurement results even more difficult to interpret. In addition, the validity of EEG brain activity assessments is not always known. A recent paper shows that an unequivocal interpretation of EEG measures is not always possible. Eijlers et al. [27] measure arousal, resulting from looking at magazine advertisements (including food ads) using EEG, and conclude that their findings cannot be taken to show ad effectivity.

A recent neurophysiological development is fNIRS (functional Near InfraRed Spectroscopy) applied to brain activity. It is a technology where NIR radiation is sent through the skull by an optode and picked up after it has been reflected by brain tissue. The hemodynamic response of the brain tissue affects what can be picked up, which is related to the activity of the brain tissue. This technology has been applied in consumer research. It is claimed that it is more portable and easier to handle than other neurophysiological measurements. However, it appears to be, to date, removed from practical (portable) applications in consumer science, and it is a laboratory tool still (but see [28].

Augmenting online measurements with neuro scientific measurements (including ANS) has also become feasible. Using the camera in respondents' (laptop) computers, heart beats can be inferred from a colour change of the face or forehead. Other ANS-devices, or even EEG, can be coupled to respondents' computers, but this will bring some additional complexity still and is not yet applicable for large consumer samples.

An example of an innovative 'field' application combining several above mentioned (near) portable technology can be found in Brouwer et al. [29]. They combined measuring EDA (Electro Dermal Activity), ECG (Electro

CardioGraphy) and EEG, allowing for extraction of several parameters, while their subjects were cooking and tasting. The subjects were voice-instructed to follow a strict cooking and tasting protocol. They cooked a meal with either chicken or mealworms, which was only revealed to them during cooking. Brouwer et al. [29] report they can, from the neurophysiological data, predict, with 82% accuracy, what dish a subject was cooking (mealworms or chicken). The aim of this study was to provide an implicit measurement method of affect or emotion during an actual cooking experience. In a follow up study, Brouwer et al. [30] collected measurements of facial expressions and wrist accelerometry in addition. **Figure 5** shows some subjects in the Brouwer et al. study [30], obviously in a laboratory setting, not in their own kitchens.



(a) (b) (c) (d)

Figure 5. Subjects in the study of Brouwer et al. (2019): (**a**) subject cooking (photograph from [30], Figure 1, p. 5. Reprinted with permission from ref. [30]. Copyright 2019 A.-M. Brouwer); (**b**) dish with mealworms in the frying pan; (**c**,**d**) subjects' faces on seeing the mealworms (Reprinted with permission from A.-M. Brouwer. Copyright 2019 A.-M. Brouwer).

Biological Measurement Technology

For sake of completeness, researchers will list some recent developments that may not strictly fit the moniker of 'neurophysiology' but are biological in their origin. One recent development is a portable glucose level sensor (**Figure 6**). More of these types of sensors have become available, and they can link (via Bluetooth) to a smartphone app or to other devices. Although some say their device is 'non-invasive', a short needle is to penetrate the skin still. Nevertheless, consumers sometimes report that they forget they are wearing the device. Finding out if truly non-invasive versions [31] exist (and are reliable) will require additional literature search.

Figure 6. Wearable glucose sensor, to be worn on (and in) the arm. (Reprinted with permission. Copyright 2022 Marieke Ubachs).

Some ‘smart watches’ can provide biological or psychophysiological data as well. Obviously, wearers of these devices are not continuously aware of the measurements being made.

Breathalysers have also been deployed to non-invasively measure physiological parameters from subjects. To what extent this is applicable, or has been applied, in a food related consumer context is not known to the authors. Obviously, it can potentially provide relevant diet-related information, including that related to flavour release, or flavour retention, in mouth or throat.

Another recent development, of quite a different nature, is what some may call ‘consumer genomics’, as in the paper by Masih and Verbeke [32], which covers the relationship between the expression of certain opioid receptors and the results of individuals on the PANAS mood scale [33]. To what extent claims in this field can already be translated to real life consumer behaviour in the food area remains to be studied.

3.2. Psychological Measurement Technologies

Any survey, or set of questions, can be given to a group of consumers, thus constituting a ‘psychological measurement’. Even when new questionnaires or new psychological scales are developed, the technology is hardly to be called new. Perhaps, with adaptive on line surveys, e.g., of the conjoint type, one can speak of some (technological) innovation. Newer developments are found in Big Data and AI technology that enable ‘very’ interactive surveying, where a path through a set of items may depend on the answers of many other respondents.

In this section, researchers will present several rather different technologies that aim to obtain information of consumers’ attitudes towards, or reported choices of, food. Many of the newer technologies are often online extensions of earlier developments. Sensometrics, covering statistics, data collection, and experimental design, is a rapidly evolving field from which they list a few innovations. AI and Big Data oriented applications form such a vast and rapidly expanding field that researchers decided not to include this area.

3.2.1. Text and Web Scrape Technology

Automatic interpretation of texts, either from the web or otherwise, made available is a relatively new and currently expanding technology, also called text mining, or text analytics. It is defined by Hearst [34] as ‘the discovery by computer of new, previously unknown information, by automatically extracting information from different written resources’. It has to be set apart from text search, as this refers to the finding of things you are looking for, so things that you already know something about (e.g., that they exist). Text mining aims to discover new things, previously unknown information, from any text source. It is already being applied in food consumer contexts [35]. In **Figure 7** (taken from [35]), the size and quality of text sources is shown. It is presented here merely to provide an indication of the possibilities of the technology, as well as for consumer research in the field. The figure shows that the best quality is provided by the scientific publishers, and the lowest is by general social media sources. In between is the internet, where ‘anything’ can probably be found.

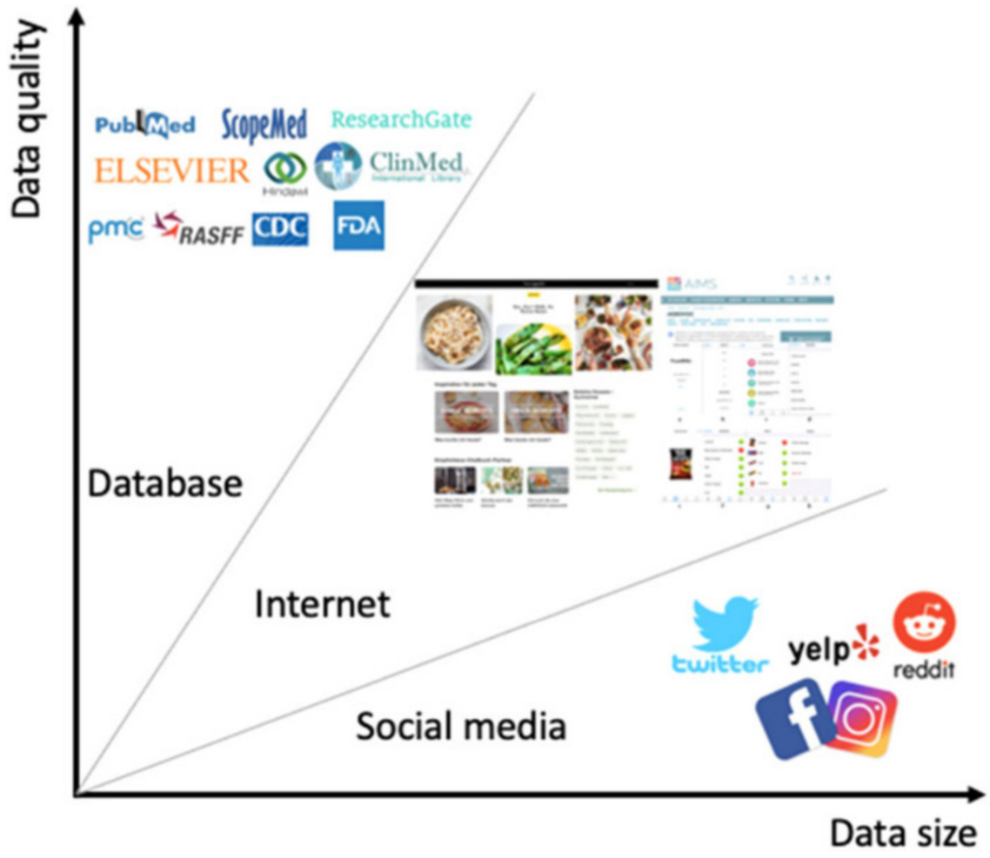


Figure 7. Text sources' quality and size, for text mining purposes, in a food and nutrition context (Figure 2 from [35]).

These days, text mining will likely also be possible from recorded spoken text, enabling even greater 'mining' possibilities.

Web-scraping is becoming a standard tool, provided by several agencies in many different contexts. A relatively recent application is the automated mining of food and recipe related data on the web. Another related technology concerns the analysis of texts from consumers that have been asked to describe a certain product. This text can be automatically processed [36]. In this way, automatic analysis of consumer prompted, written comments on specific products may reveal underlying ideas and feelings that consumers have about specific products.

3.2.2. Surveys and Ecological Momentary Assessment (EMA)

Online survey research is not new. Every thinkable set of questions can be asked to consumers, both in offline and online surroundings. The easier it is to ask questions, the easier it is to answer them, and the more pregnant the following dictum becomes: "The biggest problem in asking consumers a question, is that you will get an answer" (after E.P. Köster, personal communication).

Additional measures of an implicit nature (mouse clicking, answering speed, etc.), can also be collected online, in addition to the answers given in the survey. These are behavioural/motor, rather than psychological, measurements.

Alerting consumers at certain moments to give an answer to a question, as is possible via smartphone technology, enables a new way of surveying. When consumers are required to list their activities or food consumption at random moments during the day, a bias that may arise from filling out questions at fixed moments on the day will be countered (e.g., using the Foodprofiler [37]) or the Traqq app, [38]). Another development is EMA (Ecological Momentary Assessment [39][40]), the sending of surveys to consumers' smartphones when they are in a certain surrounding. Obviously, they have to first agree to their smartphone providing their location, and other parameters, to the investigators. If this is agreed, questions can be sent to consumers depending on a host of environmental parameters. Based on the location (in a supermarket, in a city, at a bus-station, etc.), time of day, weather conditions, previous activities (cycling, walking, shopping, relaxing), specific questions can be sent to the consumer. In this way, the investigators can ask questions appropriate to the real context the consumer is in. This technology also allows to interactively adapt a consumer's set of questions, depending on the answers of another specific consumer or a consumer segment.

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