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Complete List of Authors:	Julia, Chantal; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité; Hôpital Avicenne (AP-HP), Public Health Department Péneau, Sandrine; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité, Buscail, Camille; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité Gonzalez, Rebecca; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité Touvier, Mathilde; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité, Hercberg, Serge; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité; Hôpital Avicenne (AP-HP), Public Health Department Kesse-Guyot, Emmanuelle; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité
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Perception of different formats of front-of-pack nutrition labels according to sociodemographic, lifestyle and dietary factors in a French population

Chantal Julia, senior lecturer[1,2], Sandrine Péneau, senior lecturer [1], Camille Buscail, resident[1], Rebecca Gonzales, Post-doc, Mathilde Touvier, research fellow [1], Serge Hercberg, professor[1,2], Emmanuelle Kesse-Guyot, director of research[1]

[1] Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle (EREN), Centre d'Epidemiologie et Biostatistiques Sorbonne Paris Cité (CRESS), Inserm U1153, Inra U1125, Cnam, COMUE Sorbonne-Paris-Cité, F-93017 Bobigny, France

[2] Département de Santé Publique, Hôpital Avicenne (AP-HP), F-93017 Bobigny, France

Corresponding author/reprints requests:

Chantal Julia c.julia@uren.smbh.univ-paris13.fr

Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle (EREN), Centre de Recherche en Epidémiologie et Biostatistiques, Inserm (U1153), Inra(U1125), Cnam, COMUE Sorbonne Paris Cité, F-93017 Bobigny, France.

74 rue Marcel Cachin F-93017 Bobigny Cedex. France.

+33 1 48 38 89 53

+33 1 48 38 89 31

Last name of authors: Julia, Péneau, Buscail, Gonzalez, Touvier, Hercberg, Kesse-Guyot

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5-CNL: Five-colour nutrition label

FOP: Front-of-pack

FSA: Food Standards Agency

FSA-NPS DI : Food Standards Agency Nutrient Profiling System Dietary Index

NPS : Nutrient Profiling System

OfCom: Office of Communication

PNNS: Programme National Nutrition Santé

UK: United Kingdom

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CONFLICT OF INTEREST STATEMENT

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) No authors have support from any company for the submitted work; (2) All authors have no relationships with any company that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) All authors have no non-financial interests that may be relevant to the submitted work.

AUTHORSHIP CONTRIBUTION

CJ wrote the statistical analysis plan, analysed the data, and drafted and revised the paper. She is the guarantor. EKG participated in statistical analysis plan, analysed the data and critically revised the

paper for important intellectual content. MT CB SP RG analysed the data and critically revised the paper for important intellectual content. SH designed data collection tools, implemented the study, monitored data collection for the whole study, and critically revised the draft paper for important intellectual content. All authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. All authors have read and approved the final manuscript.

ETHICS

The NutriNet-Santé study is conducted in accordance with the Declaration of Helsinki, and all procedures have been approved by the Institutional Review Board of the French Institute for Health and Medical Research (0000388FWA00005831) and the *Commission Nationale de l'Informatique et des Libertés* (908450 and 909216). Electronic informed consent was obtained from all participants. The Nutrinet-santé study is registered under EudraCT registration number 2013-000929-31.

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Study sponsors had no part in study design, collection, analysis, and interpretation of data and the writing of the article and the decision to submit it for publication. Researchers are independent from funders and sponsors. All researchers had access to all the data

TRANSPARENCY DECLARATION

Chantal Julia affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

DATA SHARING

All necessary information is available in the paper.

ABSTRACT

Objective: Four formats for a front-of-pack (FOP) nutrition label are currently considered in France: the Nutriscore (or 5-Colour Nutrition Label, developed by a public research team), the SENS (supported by retailers), multiple traffic lights (MTL, currently used in UK) and a modified version of the Reference Intakes (mRIs, supported by industry). Our objective was to investigate the perception of these FOP labels, according to sociodemographic, lifestyle and dietary factors.

Design: Cross-sectional study

Setting: Web-based French cohort

Main outcome measure: FOP labels perception

Participants: Participants in the NutriNet-Santé cohort received a specific questionnaire pertaining to the perception of the four label formats identified. Socio-demographic, lifestyle and dietary data (three 24h dietary records) were collected through self-administered questionnaires. Mutually exclusive clusters of FOP labels perception were identified through a multiple correspondence analysis followed by a hierarchical clustering procedure. Socio-demographic, lifestyle and dietary factors associated with the clusters were explored using multivariable multinomial logistic regression. All analyses were weighted according to 2009 French census data.

Results: Among the 21,702 participants in the study, the Nutriscore received the most important number of favourable responses on positive perception dimensions by participants, followed by MTL and SENS. The 5 identified clusters were characterized by marked preferences for Nutriscore (Cluster 1, 43.2% of participants, crude N=9,399), MTL (Cluster 2, 27.3%, crude N=6,163), SENS (Cluster 3, 17.05%, crude N=3,546), mRIs (Cluster 4, 7.31%, crude N=1,632) and none of the presented formats (Cluster 5, 5.10%, crude N=965). The Cluster 1 (Nutriscore) was associated with lower adherence to nutritional recommendations, while Cluster 2 (MTL) was associated with younger age and higher level of education.

Conclusion: The Nutriscore appears to have a wide reach in the population and to appeal to subjects with lower adherence to nutritional recommendations. As such, it would appear as a legitimate choice for policy makers.

ARTICLE SUMMARY

- Cross-sectional study in a large population using validated data collection tools.
- Investigation of multiple dimensions of the perception of FOP labels (awareness, liking, perceived cognitive workload and trustworthiness), across various formats that are currently proposed in the French debate on FOP nutrition labelling.
- Identification of clustered preferences towards each type of format, and investigation of the association between socio-demographic and dietary factors with FOP label preferences
- Sample consisting of volunteer subjects included in a cohort study on nutrition, who are therefore more likely health conscious.
- Focus on the perception of FOP labels, and not on understanding or use of FOP labels in purchasing situations.

INTRODUCTION

Preventing non-communicable diseases has become a top priority for most industrialized countries, as they represent a major part of the burden of diseases (1). Diet has been recognized as a key modifiable factor which can influence – as preventive or risk factor – a wide range of non-communicable diseases, from cardiovascular disease to cancer, type 2 diabetes, metabolic syndrome or obesity (2-4). Given its potential lever for improvement of the health status of the population, most western countries have invested in state-level public health programs on nutrition, promoting healthy diets and physical activity (5-7). In France, the National Nutrition and Health Program (Programme National Nutrition et Santé, PNNS), launched in 2001 (8), sets a regulatory environment that promotes synergistic actions towards healthy eating and physical activity. The most pervasive actions that have been taken towards the population have consisted in the dissemination of nutrition recommendations in multimedia campaigns and booklets (9;10). Those recommendations act upon the nutrition knowledge of individuals, prompting them to modify their dietary behaviour by promoting consumption of some food groups (e.g. fruits and vegetables, whole-grain cereals, water) or limiting excessive intakes of others (saturated fat, added sugar and sodium) (11). Recently, novel complementary strategies have been put forward in a report to the French Minister of Health in 2014, highlighting the need for specific measures to modify the nutritional environment beyond the actions at the individual level (12). The report stressed in particular measures pertaining to nutrition labelling, in the form of a simplified front-of-pack (FOP) nutrition label, advertising regulation and nutritional taxation (12). Among the proposals of this report, the implementation of a FOP nutrition labelling system was considered as an effective opportunity by the Health Minister, and its principle was introduced in the 2016 French Health Law (13). However, though the initial report contained a detailed proposal for the label supported by scientific studies (14-26) and independent government agencies evaluations (27;28) in the form of the 5-Colour Nutrition Label (5-CNL), alternative proposals were put forward during the debate by industry and retailers, in a vast lobbying campaign (29). Finally, four alternative formats emerged in the debate: the 5-CNL (with a graphical format termed Nutriscore), SENS (developed and promoted by retailers), Multiple Traffic Lights (MTL, currently used in the United Kingdom, UK) and

a modified version of the Reference Intakes (mRIs, promoted by industry) (**Figure 1**). However, to date, no scientific study has directly compared the perception of the four proposed formats. Some studies tend to indicate that the 5-CNL would be more effective than MTL or RIs (16-18;30), but no data has been published on the mRIs or the SENS formats.

The objective of the present study was therefore to investigate the perception of the four formats that have been put forward in France in the debate on FOP nutrition labelling, in a comparative design carried out in the NutriNet-Santé cohort.

MATERIAL AND METHODS

Population

Participants were selected from the NutriNet-Santé cohort. Briefly, the NutriNet-santé study is a prospective cohort study set in France in which inclusion and follow-up of volunteer participants are performed on the Internet (31). The main objectives of the NutriNet-santé study are: 1) to investigate the relationship between nutrition and health outcomes; and 2) to investigate the determinants of dietary patterns and nutritional status. Inclusion in the study began in May, 2009, and is still ongoing. Volunteer participants aged >18 years-old subscribe to the study, and are included when they have completed a set of questionnaires assessing: diet (through repeated 24h dietary records), physical activity, anthropometry, lifestyle and socio-economic conditions and health status. These five types of questionnaires are repeated yearly and have been validated against traditional assessment methods (paper or interview by dieticians) (32-34). Once the subject is included in the cohort, he receives monthly web-questionnaires pertaining to various aspects of dietary behaviour, physical activity and health. One of these questionnaires pertained to the perception of the various FOP labelling systems that have been proposed in the French context and was sent to all participants in the cohort in June 2016.

Detailed information on the NutriNet-Santé study can be found elsewhere (31).

Ethics

The NutriNet-Santé study is conducted in accordance with the Declaration of Helsinki, and all procedures have been approved by the Institutional Review Board of the French Institute for Health and Medical Research (0000388FWA00005831) and the *Commission Nationale de l'Informatique et des Libertés* (908450 and 909216). Electronic informed consent was obtained from all participants. The NutriNet-Santé study is registered under EudraCT registration number 2013-000929-31.

Perception of FOP labels

A specific questionnaire was developed to investigate the perception of the 4 various formats of FOP labelling that have been proposed in the French current political debate on FOP labelling, based on previous research on the topic (17;35). A brief presentation of the four FOP labels was provided for the participants at the beginning of the questionnaire. The presentation made no mention of the origin or support by researchers or industry of each format, in order not to influence the participants based on this information.

Briefly, the Nutriscore, developed by the EREN scientific research team, and based on the British Food Standards Agency nutrient profiling system and adapted for the French context by the High Council for Public Health (28) presents for each food or beverage the overall nutritional quality on a 5-point colour-coded scale from Green to Red (**Figure 1**). SENS, supported by retailers, is based on a nutrient profiling system developed by a research team, and presents for each food or beverage a recommended frequency of consumption, with a 4 points colour-coded scale (Green, Blue, Orange and Purple) (**Figure 1**). MTL, implemented in Great Britain since 2005 presents the numeric values of the contribution of a portion of the food to the intakes in a balanced diet (in grams and percentage of reference intakes, corresponding to the reference intakes label) for energy, fats, saturated fats, sugar and sodium, with a colour-coding (Green, Amber and Red) for each of these components of the food (**Figure 1**). The Modified Reference Intakes (mRIs) present the numeric values of the reference intakes, in both grams and percentage of reference intakes, with bars varying in height depending on the amount of the component in the food (**Figure 1**).

Overall, 13 questions were asked on various aspects of liking (e.g. “This is my preferred FOP label”), trustworthiness (e.g. “This FOP label provides reliable information”), awareness (e.g. “This FOP label is easy to identify”) and perceived cognitive workload (e.g. “This label is too complex for understanding”) (**see Supplemental table 1**). For each question, subjects were asked to select among the four formats the label that best corresponded to them. The participants could also select that ‘none’ of the proposed labels corresponded to his/her perception.

Socio-demographic and lifestyle data

Socio-demographic and lifestyle data were collected through self-administered questionnaires and included age, gender, education (no diploma and up to secondary education, University ≤ 2 years, University > 2 years), marital status (in couple, single/divorced/widowed), income per household unit (36) (<1200/month, 1200 – 1800, 1800 – 2700, ≥ 2700 €/month) and smoking status (current smoker, former smoker and never smoker). Physical activity was computed using self-declared data from the validated International Physical Activity Questionnaire (low, moderate and high physical activity levels) (37). The data collected in the questionnaire closest in time to the questionnaire pertaining to FOP labels perception were taken into account for the analyses.

Dietary data

Dietary data were derived from three repeated 24-hour records randomly distributed in a two-week period, with two week days and one week-end day. Food consumption was weighted according to the day of the week of each record. The participants are asked to estimate the portion size for each reported food and beverage item using validated photographs (38). Nutrient intake was computed using a published food composition database reflecting foods usually consumed in the French diet (39). Under- reporters for energy intake were identified using Goldberg/Black’s method and were excluded (40). The dietary data from the 24h dietary record in the NutriNet-Santé study have been validated against record by phone by trained dieticians, and against biomarkers of nutritional status (33;41;42).

Statistical analysis

For the present study, all participants who had completed the questionnaire on the perception of FOP labels, and having completed information on all covariates were eligible to the present study. Subjects were excluded if they stated that they never engaged in grocery shopping. The records and questionnaires closest to the questionnaire pertaining to FOP labels perception were taken into account for the analyses.

Weighting of the data

All data were weighted using the SAS CALMAR (CALage sur MARges) macro developed in France by the Institute of National Statistics (INSEE) to weight survey data to be representative of the French census population (43). Data used for weighting were sex, age and educational level.

Adherence to dietary recommendations

Adherence to French dietary recommendations was assessed using a modified version of the PNNS guidelines score (namely, the "*Programme National Nutrition Santé"*-guideline score, PNNS-GS), taking into account only dietary recommendations. The PNNS-GS development, including food groupings, serving sizes, scoring, cut-off and penalties, has been previously described in detail (44). Briefly, this 15-point score is based on French national guidelines and includes 13 components. The eight components referring to food serving recommendations and four components referring to moderation in consumption were included in the modified version of the PNNS-GS (mPNNS-GS) (45). The last component focusing on adherence to physical activity recommendations was not taken into account.

A penalty for overconsumption was assigned to individuals with energy intakes higher than estimated energy expenditure (44). Age and self-reported weight and height at inclusion were used to estimate Schofield's basal metabolic rate (BMR) (46). Energy expenditures were estimated using BMR and physical activity level. In case of energy intake greater than 5% over the estimated energy expenditure, an identical part was subtracted from the score. Quartiles of mPNNS-GS were computed and used throughout the analyses.

Dietary clusters identification

The responses from the 13 "perception" questions were used in a multiple correspondence analysis, which yielded 4 dimensions of FOP labelling perception. The dimensions were selected based on their adjusted inertia (respectively 33.6%, 23.0%, 18.4% and 17.2% for a total of 92.3%). The selected dimensions were used as input variables in a two-ways clustering procedure based on hierarchical and K-means methods (SAS CLUSTER and FASCLUST procedures). The plot of semi-partial R^2, the semi-partial T^2 and the Cubic Clustering Criterion (CCC) by the number of clusters were used to identify the optimal number of clusters.

Statistical analysis

All analyses were weighted according to the CALMAR macro, except the clustering procedure for which no weighting option is available. The responses to each of the 13 questions were mapped across clusters, in order to identify the FOP perception characteristics of each cluster. Socio-demographic, lifestyle and dietary variables were mutually adjusted against clusters in a multivariable multinomial regression. Adjusted-percentages for each socio-demographic, lifestyle and dietary characteristic were extracted from this procedure across clusters.

All tests were two-sided and a P value <0.01 was considered significant, given the high number of statistical tests performed and the large sample size. Statistical analyses were performed using SAS Software (version 9.3, SAS Institute Inc, Cary, NC, USA).

RESULTS

Overall, 38,604 subjects completed the questionnaire pertaining to the perception of the various FOP labels formats. Among these, 714 were excluded because they never engaged in grocery shopping. Among the 37,890 remaining subjects, 16,188 were excluded for incomplete data on covariates (the vast majority of which (N=13,066) for incomplete data on mPNNS-GS computation, which requires the presence of three 24h records, frequency questionnaire on alcohol consumption and frequency of seafood consumption, leading to an overall sample of 21,702 participants for analysis.

Characteristics of the crude and weighted sample are presented in **Table 1**. The crude sample exhibited a higher percentage of females (73.4%), older subjects (68.4% were ≥ 50 years-old), educated (37.5% had above 2 years of university training) and with high incomes (38.5% had incomes >2700€/month).

Overall, the Nutriscore was the label receiving the most important number of favourable responses on positive perception dimensions by participants, followed by MTL and SENS (43.8% of participants considered the Nutriscore as their preferred FOP label, followed by 24.9% for MTL and 17.2% for SENS) (**Table 2**). Conversely, RIs yielded the highest number of responses on negative dimensions of perception (complexity and time processing). A majority of participants considered that none of the proposed labels were guilt-laden (50.2%), followed by SENS (21.2%)

The clustering procedure resulted in the identification of 5 mutually exclusive groups of subjects according to their perception of FOP nutrition labels. Clusters represented 43.2% (crude N=9,399), 27.3% (crude N=6,163), 17.05% (crude N=3,546), 7.31% (crude N=1,632) and 5.10% (crude N=965) of participants, respectively. The mapping of perception responses across clusters showed that each cluster was characterized by a marked preference for one of the proposed FOP nutrition label formats: Cluster 1 displayed a marked preference for the Nutriscore, Cluster 2 for the MTL, Cluster 3 for the SENS, Cluster 4 for the RIs and Cluster 5 for none of the presented labels (**Figure 2**). Therefore, clusters were termed according to their label preference. These preferences across cluster were particularly prominent for the following aspects: label wanted on the front of the packages (>85% for each specific FOP label in their respective cluster), preferred label (>80% for each specific label in their respective cluster), label allowing to choose healthier products (>65% for each specific label in their respective cluster), trustworthiness (>74% for each specific label in their respective cluster) (**Figure 2**). However, for some dimensions of perception, responses were somewhat less marked for each specific FOP label, and more concurrent across clusters. For example, >23% of participants in all clusters considered that the Nutriscore was quick to process, >19% considered it easy to identify, and >17% considered it easy to understand (**Figure 2**). Conversely, >20% of participants in all clusters considered the mRIs to be too complex for understanding (except in its own where it obtained 11% of

opinions), >19% considered it too long to understand (except in its own cluster, with 12% of opinions), and was considered as the least appreciated FOP nutrition label for 66.7% of subjects in the Cluster Nutriscore, 61.9% of subjects in the Cluster SENS, 39.9% of subjects in the Cluster MTL and 10.8% of subjects in the Cluster None (**Figure 2**). Finally, participants considered that none of the presented labels was guilt-laden: 87.1% of Cluster None, 50.0% of Cluster Nutriscore, 47.9% of Cluster MTL, 47.8% of Cluster mRIs and 44.8% of Cluster SENS (**Figure 2**).

Multivariable adjusted socio-demographic characteristics according to specific clusters are shown in **Table 3**. Less educated subjects were more frequent in Cluster None and Cluster mRIs and highly educated subjects in Cluster MTL (**Table 2**). Smokers were more likely in Cluster None, while never smokers were more likely in Cluster Nutriscore. Subjects with low physical activity were more likely in Cluster SENS and Cluster Nutriscore (**Table 2**). Finally, subjects with lower adherence to dietary recommendations (Quartile 1 of mPNNS-GS) were more likely in Cluster None and Cluster Nutriscore while subjects with high adherence to dietary recommendations (Quartile 4 of mPNNS-GS) were more likely in Cluster mRIs and Cluster MTL (**Table 2**).

DISCUSSION

Our study showed that the perception of FOP labels can be clustered according to consistent preferences for specific formats. Among the proposed labels in the current French debate, the Nutriscore appeared to be the most preferred format, followed by MTL. Moreover, though each cluster presented marked preferences for one type of format or another, the Nutriscore appeared to reach to participants beyond its specific cluster, as it was considered easy to identify and understand by a significant number of participants in other clusters. Finally, socio-demographic characteristics appeared to be associated with each cluster, with a specific cluster (Cluster 5, None), concentrating high percentages of subjects presenting disadvantaged socio-demographic characteristics (lower levels of education) and lifestyle risks (smoking, low level of physical activity and low adherence to dietary recommendations).

Compared to a previous study conducted in early 2015 using a similar methodology and among participants in the same cohort study, the results of the present analyses show that the reach of the Nutriscore has somewhat broadened since then (17). The Nutriscore appeared to have a wide reach in the population, and to appeal to subjects with lower adherence to dietary recommendations. This result shows that the Nutriscore may be an effective complementary strategy to current public health nutrition policies, which promote healthy eating through widely disseminated nutritional recommendations (47). Though this strategy has led to an increase in the knowledge of nutritional recommendations, consumers somehow struggle to translate such advice into action (48;49). Disseminated nutrition information is suggested to appeal more to those already having the capacity to implement nutritional knowledge (through higher education or income), and may lead to an increase in social disparities in health (50;51). Appealing, through complementary strategies, such as FOP nutrition labels, to those lacking the potential to translate nutritional recommendations or to those to which it would most benefit therefore appears of crucial importance.

The MTL appeared as the second preferred FOP label in the population, particularly in younger subjects, with university education and lower incomes. Moreover it was considered to be providing reliable and useful information beyond its own cluster. The fact that direct numeric information on nutrient content (such as the information provided by mRIs) received a much lower support in the population shows that the appeal of the MTL is very probably associated with the colour feature of this FOP label (52), as multiple numeric information are typically considered difficult to understand (53). Indeed, compared to mRIs, the MTL only adds an interpretation of the level of nutrients using a colour-coding. However, the interpretation of the colour-coding has appeared to be challenging in certain populations (52). Indeed, MTL is a nutrient-specific FOP label, giving individual information for energy and four nutrients (sugars, fat, saturated fat and salt). Multiple nutrient-related information implies first that consumers are able to identify the nutrients that are referred to, and second, that they are able to prioritize the information provided for each nutrient (35;54). Indeed, MTL can lead to conflicting choice options: for example, the comparison between two products, with the same number of nutrients coded in ‘red’, but not for the same nutrients (e.g. one with a ‘red’ code for sugar and the

other for saturated fatty acids) implies for the consumer to be able to single out one of the nutrients in order to make a choice (55). These characteristics of the label may in part explain the fact that the MTL appeared to appeal more particularly to young, educated subjects with a high level of adherence to nutritional recommendations. This more favourable perception among these participants may stem from their higher nutritional knowledge, which allows them to better interpret the label and act upon it in purchasing situations (53;55). However, this specific reach in terms of population might also lead to widen inequalities in health and nutrition if implemented in the overall population (56).

The SENS system was the preferred system for 17% of the population, more particularly in households with children. The graphical system the SENS originated from was developed by a marketing team from a retailer in September 2014, and received later support from the French retailers' federation (29). As for Nutriscore or MTL, it is based on colour coding (though not based on the polychromatic Green-Red scale), with the addition of recommended frequencies of consumption for each level of the label. This latter feature may in part explain the higher appeal of the SENS system on participants with children, as it gives a more specific guidance for consumption, which can be used for children. However, these specific consumption frequencies for each level of the label could also be interpreted as an oversimplification and a form of paternalism for many consumers (57). This may be one of the reasons the SENS label was considered as a guilt-laden label for 21.2% of the population.

Moreover, though Nutriscore and MTL rely on the well-known polychromatic scale from green to red (corresponding to recognized signals), which are easier to interpret, the SENS colour-coding does not refer directly to any known colour scale (its levels are Green-Blue-Orange-Purple). Colours are considered helpful to generally increase the salience of a FOP label, however, studies that have shown a specific advantage of colour-coding have used readily interpretative colour-coding (57-60). In the study by Bialkova et al., which used polychromatic RIs, but with no readily-interpretative colours (yellow, orange, purple, blue), the polychromatic RIs indeed had lower performance than monochromatic RIs (58). Therefore, beyond preference only, the use of highly interpretable colours (e.g. 'Green' and 'Red') in a FOP labelling system might be an important feature of a colour coding.

Finally, our study shows that a portion of the population appeared to disregard or even reject FOP nutrition labels entirely. Indeed, participants in Cluster 5 (None, corresponding to 5.1% of the population) consistently responded 'None' for all dimensions of perception that were investigated. Moreover, the socio-demographic characteristics of this specific population suggested that they may in fact be more vulnerable and more at nutritional risk than the rest of the population. Indeed, this cluster included more specifically older participants, subjects with lower educational levels, current smokers and subjects with lower adherence to nutritional recommendations. This result is in line with a study in Australia showing that males and subjects with lower socio-economic status were more likely to report no preference for a FOP label (61). These results also pose a challenge to the design of efficient public health policies, as some of the subjects who would certainly benefit from them appear to reject them. Novel and targeted interventions in public health nutrition should therefore be devised to appeal to this vulnerable population to entice them towards healthier diets, taking into account the broader environment related to risk behaviours (62). Alternatively, policies targeting the environment, and not depending on individual choices, such as the reformulation of existing products, may have an indirect impact on these populations (63).

Strengths of our study include its large sample size, and the use of validated dietary collection data, using repeated dietary records (33). Moreover, we were able to investigate multiple dimensions of the perception of FOP labels (awareness, liking, perceived cognitive workload and trustworthiness), across various formats that are currently proposed in the French debate on FOP nutrition labelling. Finally, we were able to identify clustered preferences towards each type of format, and relate them to socio-demographic and dietary factors, which highly contributed to the interpretation of such preferences in a public health perspective.

Our study is subject to some limitations. First, our sample consists of volunteer subjects included in a cohort study on nutrition, who are therefore more likely health conscious. However, our data shows a wide variety of dietary profiles, somewhat lessening the importance of this bias. Moreover, the use of weighting partially controlled for the selection bias of our study population (64). Second, our study focused on the perception of FOP labels, and not on understanding or use of FOP labels in purchasing

situations. However, following the theoretical framework for the use of FOP nutrition labels, favourable perception is a crucial pre-requisite for the efficiency of a given label (65;66).

To conclude, FOP nutrition labels could be useful strategies to tackle social inequalities in nutrition and health, provided that the graphical format that is selected has a wide reach in the population. This is all the more important that subjects who are more concerned about their diet (and more likely to have a healthier diet), are also more likely to use a nutrition label when grocery shopping (67). As such, the Nutriscore would appear as a legitimate choice for policy makers in France, as it might bring subjects with lower adherence to nutritional recommendations towards healthier diets.

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FIGURE LEGENDS

Figure 1: Formats proposed for a front-of-pack nutrition label in France.

Caption:

Nutriscore developed by the EREN research team, is based on the British Food Standards Agency nutrient profiling system and presents for each food or beverage the overall nutritional quality on a five-point colour-code scale from Green to Red.

SENS, supported by retailers, is based on a nutrient profiling system developed by a research team, and presents for each food or beverage a recommended frequency of consumption, with a four points colour-coded scale (Green, Blue, Orange, Purple)

Multiple Traffic Lights, supported by industry, and implemented in Great Britain since 2005 presents the numeric values of the contribution of a portion of the food to the intakes in a balanced diet (in grams and percentage of reference intakes, corresponding to the reference intakes label, RI) for energy, fats, saturated fats, sugar and sodium, with a colour-coding (Green, Amber and Red) for each of these components of the food

Modified Reference Intakes (mRIs) present the numeric values of the reference intakes, in both grams and percentage of reference intakes, with bars varying in height depending on the amount of the component in the food.

Figure 2: Responses to each of the dimensions of perception in the various clusters

Caption: Each circle represents a cluster, each response to a dimension is scaled within the cluster. Positive dimensions are situated on the right hand side of the figure, while negative dimensions are situated on the left hand side of the figure

Table 1 Characteristics of the study population, crude and after weighting

		Crude		Weighted
		n	%	%
Sex				
	Men	5768	26.58	39.97
	Women	15934	73.42	60.03
Age				
	18-29 years-old	968	4.46	12.28
	30-49 years-old	5900	27.19	31.05
	50-64 years-old	7899	36.40	29.39
	≥ 65 years old	6935	31.96	27.28
Educational level				
	Up to secondary	6804	31.35	70.54
	University, up to two years	6750	31.10	13.86
	University, ≥ 3 years	8148	37.54	15.60
Income per consumption unit				
	<1200/month	2068	9.53	20.28
	[1200 - 1800[€/month	4766	21.96	30.24
	[1800 - 2700[€/month	6514	30.02	28.67
	≥ 2700 €/month	8354	38.49	20.81
Household composition				
	Adults only	17118	78.88	78.05
	Adults and children	4584	21.12	21.95
Smoking status				
	Current smoker	1923	8.86	10.16
	Former smoker	8710	40.13	39.81
	Never smoker	11069	51.00	50.03
Physical activity level				
	High	8007	36.90	39.01
	Moderate	9128	42.06	37.28
	Low	4567	21.04	23.72
mPNNS-GS				
	Quartile 1	5425	25.00	23.70
	Quartile 2	5582	25.72	23.86
	Quartile 3	5933	27.34	26.20
	Quartile 4	4762	21.94	26.24

Weighting was obtained using the SAS CALMAR Macro

Table 2 Crude percentage of responses to the dimensions of perception of FOP labels

	Nutriscore	MTL	SENS	GDA	None
This FOP label is helpful to choose healthier products	40.02	26.93	17.33	9.14	6.57
I want to see this FOP label on the front of packages	44.22	25.15	17.15	7.43	6.05
This is my preferred FOP label	43.79	24.92	17.17	6.68	7.45
This FOP label provides me with the information I need	24.51	43.06	15.78	11.44	5.21
This FOP label is trustworthy	37.64	28.83	15.23	8.52	9.79
This FOP label provides reliable information	26.76	40.32	10.55	11.75	10.62
This FOP label is easy to identify	62.53	8.78	21.37	2.75	4.56
This label is easy to understand	52.22	7.86	33.5	3.43	2.99
This FOP label is quick to process	64.09	8.07	22.27	2.9	2.68
This FOP label is too complex for understanding	4.49	19.9	5.7	48.22	21.7
This FOP label takes too long to understand	2.52	25.45	2.86	50.81	18.36
This is the FOP label I appreciate the least	9.67	12.58	17.44	51.33	8.98
This FOP label is guilt-laden	12.42	9.32	21.19	6.83	50.23

Table 3 Multivariable adjusted socio-demographic, lifestyle and dietary characteristics according to the various clusters of preference for FOP nutrition labeling

		Nutriscore	MTL	SENS	GDA	None	*P*
		43.23	27.31	17.05	7.31	5.10	
Sex							*<0,0001*
	Men	**41.88**	37.23	37.48	**35.67**	40.14	
	Women	58.12	62.77	62.52	64.33	59.86	
Age							*<0,0001*
	18-29 years-old	11.11	**13.90**	11.06	11.82	3.93	
	30-49 years-old	64.66	68.43	67.53	66.86	64.92	
	50-64 years-old	21.40	15.86	19.04	18.05	25.76	
	≥ 65 years old	2.84	1.81	2.37	3.27	**5.40**	
Educational level							*<0,0001*
	Up to secondary	72.64	67.59	72.05	77.71	**77.84**	
	University, up to two years	15.26	16.81	15.72	12.79	12.21	
	University, ≥ 3 years	12.09	**15.61**	12.23	9.50	9.95	
Income per consumption unit							*<0,0001*
	<1200/month	14.57	**20.07**	16.36	17.17	13.95	
	[1200 - 1800[€/month	32.61	31.47	35.57	35.71	36.83	
	[1800 - 2700[€/month	30.96	29.29	29.41	29.17	30.45	
	≥ 2700 €/month	**21.85**	19.16	18.66	17.96	18.77	
Household composition							*<0,0001*
	Adults only	87.76	88.57	86.99	88.60	**90.35**	
	Adults and children	12.24	11.43	**13.01**	11.40	9.65	
Smoking status							*<0,0001*
	Current smoker	10.91	11.33	9.94	9.35	**15.59**	
	Former smoker	31.74	34.95	34.21	35.63	32.69	
	Never smoker	**57.35**	53.72	55.85	55.02	51.73	
Physical activity level							*<0,0001*
	High	31.73	34.19	31.12	**35.93**	29.38	
	Moderate	40.97	44.91	41.20	41.62	43.90	
	Low	27.30	20.90	**27.68**	22.44	26.71	
mPNNS-GS							*<0,0001*
	Quartile 1	28.28	25.09	23.90	21.63	**32.47**	
	Quartile 2	25.90	22.09	26.67	20.08	30.08	
	Quartile 3	26.86	28.44	26.96	30.87	21.86	
	Quartile 4	18.96	24.37	22.47	27.42	**15.59**	

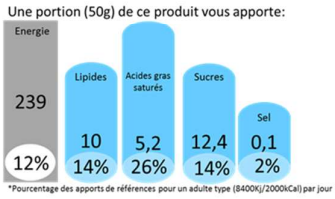
Mutually adjusted percentages obtained with multinomial regression

Figure 1

Nutriscore

SENS

Modified Reference Intakes



Multiple Traffic Lights

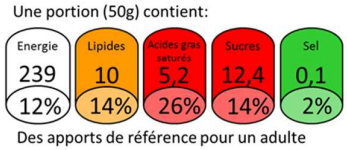
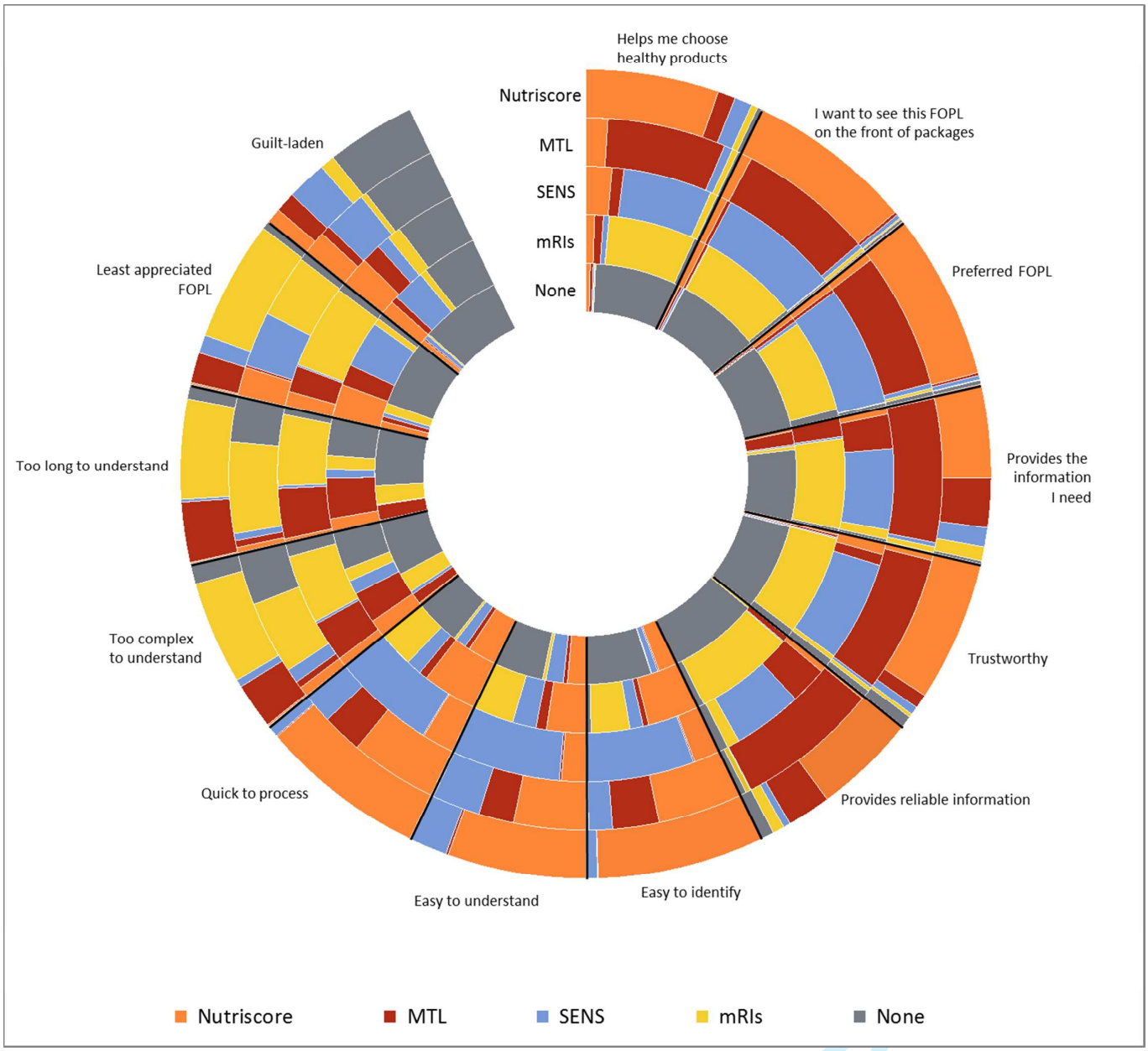


Figure 2


Helps me choose healthy products
I want to see this FOPL on the front of packages
Preferred FOPL
Provides the information I need
Trustworthy
Provides reliable information
Easy to identify
Easy to understand
Quick to process
Too complex to understand
Too long to understand
Least appreciated FOPL
Guilt-laden
Nutriscore
MTL
SENS
mRIs
None
Nutriscore
MTL
SENS
mRIs
None

Online Supplemental material

Supplemental Table 1 Questionnaire used to assess perception of the various FOP nutrition labels (French version and English translation)

Question (English Translation)	Question (Original question in French)
This FOP label is helpful to choose healthier products	Ce logo aide à choisir des produits meilleurs pour la santé
I want to see this FOP label on the front of packages	Je veux qu'il soit présent sur les emballages
This is my preferred FOP label	C'est mon logo préféré
This is the FOP label I appreciate the least	C'est le logo que j'aime le moins
This FOP label provides me with the information I need	Ce logo m'apporte l'information dont j'ai besoin
This FOP label is trustworthy	Ce logo m'inspire confiance
This FOP label provides reliable information	Ce logo permet d'avoir une information fiable
This FOP label is easy to identify	Ce logo est facile à repérer
This label is easy to understand	Ce logo est facile à comprendre
This FOP label is quick to process	Ce logo permet d'avoir une information rapide
This FOP label is too complex for understanding	Ce logo est trop compliqué à comprendre
This FOP label takes too long to understand	Ce logo est trop long à comprendre
This FOP label is guilt-laden	Ce logo est culpabilisant

Online Supplemental material

Supplemental Table 2 responses to perception questions according clusters of preference for FOP nutrition labeling

Liking

	Nutriscore	MTL	SENS	mRIs	None
This FOP label is helpful to choose healthier products					
Nutriscore	74.32	13.93	19.21	7.81	4.84
SENS	9.91	5.45	65.23	4.96	1.54
MTL	9.78	75.12	8.65	7.54	3.2
mRIs	3.64	3.86	5.23	76.19	1.03
None	2.36	1.64	1.68	3.51	89.4
I want to see this FOP label on the front of packages					
Nutriscore	93.45	7.64	6.32	6.89	3.1
SENS	2.34	2.99	88.89	0.66	2.35
MTL	1.73	86.27	2.92	2.75	2.73
mRIs	0.82	2.21	0.59	86.66	0.81
None	1.66	0.89	1.28	3.04	91
This is my preferred FOP label					
Nutriscore	93.51	6.24	6.18	5.94	3.33
SENS	2.3	3.12	88.31	2.9	1.05
MTL	1.53	86.06	2.54	3.23	1.7
mRIs	0.33	1.84	0.42	81.23	0.47
None	2.33	2.74	2.55	6.7	93.45
This is the FOP label I appreciate the least					
Nutriscore	1.08	17.92	10.9	28.78	6.79
SENS	10.36	34.9	1.31	41.12	3.96
MTL	16.91	1.51	19.14	18.16	5.23
mRIs	66.88	39.88	61.86	5.85	10.78
None	4.77	5.78	6.78	6.09	73.24

Online Supplemental material

Awareness and trustworthiness

	Nutriscore	MTL	SENS	mRIs	None
This FOP label provides me with the information I need					
Nutriscore	52.36	2.01	6.25	0.56	4.21
SENS	10.83	2.66	59.59	1.74	1.71
MTL	27.37	91.49	25.14	16.79	14.24
mRIs	7.78	3.58	6.87	78.6	3.66
None	1.67	0.25	2.16	2.31	76.17
This FOP label is trustworthy					
Nutriscore	79.33	4.82	9.29	3.48	3.67
SENS	4.55	1.79	74.04	0.98	1.5
MTL	7.98	87.15	8.04	1.98	1.21
mRIs	1.96	2.43	3.35	87.89	0.28
None	6.18	3.81	5.29	5.67	93.34
This FOP label provides reliable information					
Nutriscore	57.78	2.37	5.76	1.95	0.23
SENS	3.92	0.48	50.74	0.88	0.12
MTL	24.47	90.22	27.44	4.67	1.53
mRIs	6.54	3.18	9.22	87.05	2.36
None	7.29	3.75	6.84	5.45	95.75
This FOP label is easy to identify					
Nutriscore	93.08	53.69	19.15	45.28	20.69
SENS	6.03	15.02	79.02	11.56	6.82
MTL	0.34	29.44	0.99	4.83	1.41
mRIs	0.08	0.6	0.32	33.66	0.78
None	0.47	1.25	0.53	4.68	70.29

Online Supplemental material

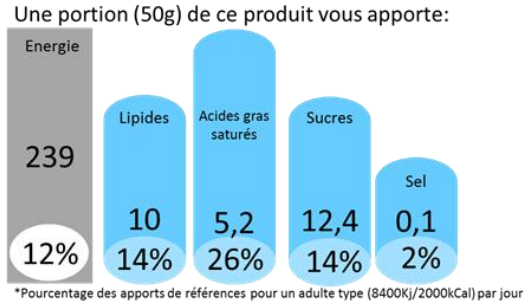
Perceived cognitive workload

	Nutriscore	MTL	SENS	mRIs	None
This label is easy to understand					
Nutriscore	77.11	45.5	17.55	33.92	19.4
SENS	20.75	30.45	80.77	20.47	18.54
MTL	1.41	22.27	1.58	9.16	4.46
mRIs	0.51	1.46	0.09	35.6	3.72
None	0.22	0.33	0	0.85	53.88
This FOP label is quick to process					
Nutriscore	92.72	55.07	23.2	47.31	30.42
SENS	6.18	18.75	75.65	13.43	11.67
MTL	0.62	25.17	0.75	7.31	5.22
mRIs	0.38	0.88	0.39	31.18	2.88
None	0.1	0.12	0.01	0.78	49.82
This FOP label is too complex for understanding					
Nutriscore	0.99	6.38	6.36	14.98	2.75
SENS	4.23	9.09	1.86	12.2	3.51
MTL	25.49	4.24	30.07	27.56	11.35
mRIs	57.73	46.53	50.78	10.9	21.55
None	11.56	33.77	10.92	34.35	60.84
This FOP label takes too long to understand					
Nutriscore	0.77	3.45	2.37	11.12	0.65
SENS	1.57	4.47	2.19	7.43	0.81
MTL	33.71	4.33	36.95	35.12	16.19
mRIs	55.76	58.12	52.13	12.73	19.83
None	8.19	29.63	6.36	33.6	62.51
This FOP label is guilt-laden					
Nutriscore	8.33	14.8	21.33	12.13	4.97
SENS	22.37	27.72	9.68	28.3	4.59
MTL	11.15	5.87	14.04	5.84	1.59
mRIs	8.23	3.73	10.16	5.93	1.73
None	49.93	47.89	44.78	47.8	87.12

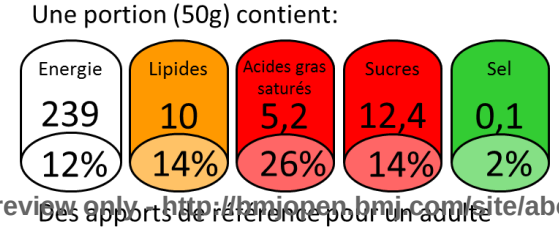
Nutriscore

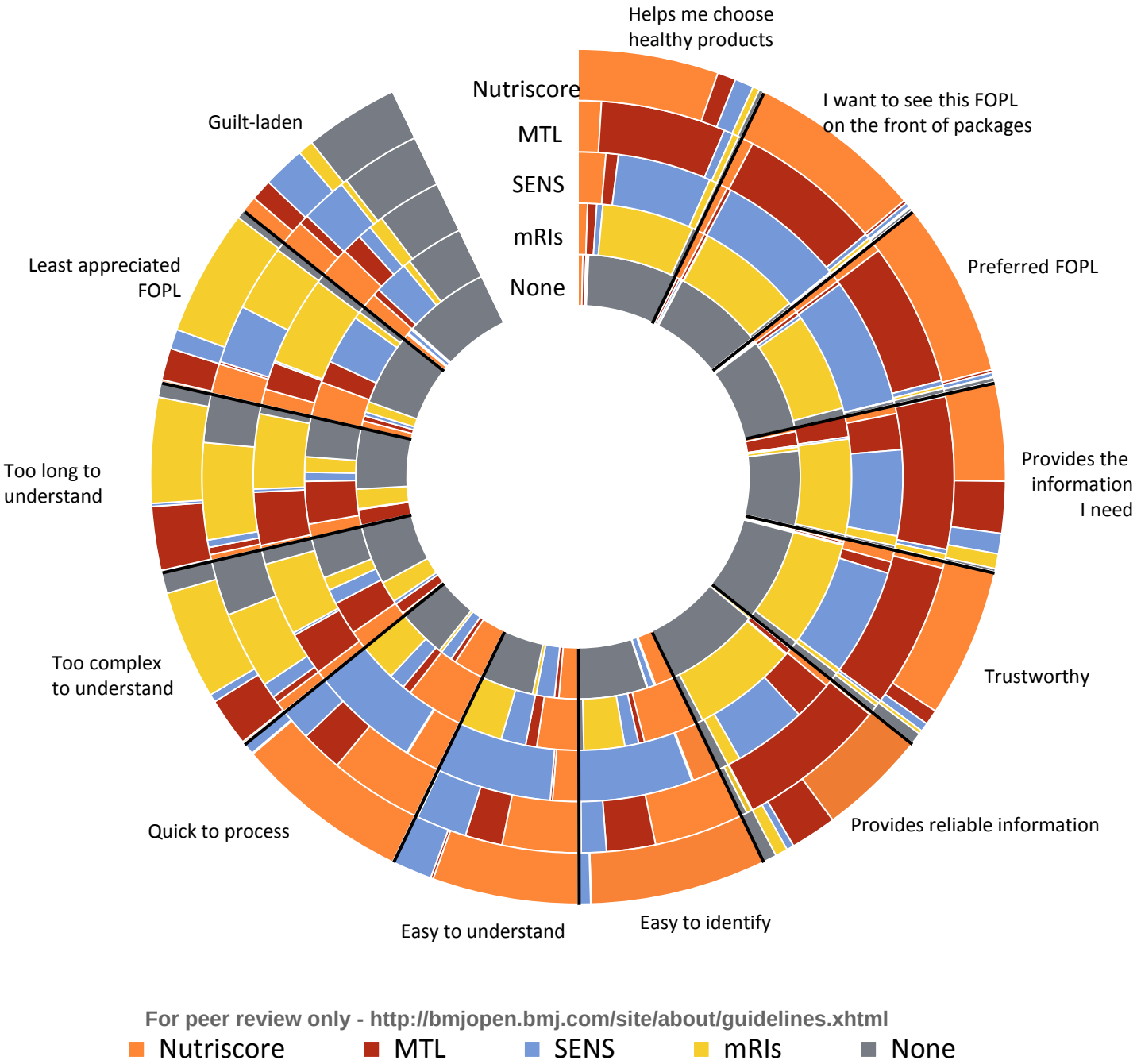
SENS

Modified Reference Intakes



Multiple Traffic Lights





Online supplementary material

Supplemental Table 1 Questionnaire used to assess perception of the various FOP nutrition labels (French version and English translation)

Question (English Translation)	Question (Original question in French)
This FOP label is helpful to choose healthier products	Ce logo aide à choisir des produits meilleurs pour la santé
I want to see this FOP label on the front of packages	Je veux qu'il soit présent sur les emballages
This is my preferred FOP label	C'est mon logo préféré
This is the FOP label I appreciate the least	C'est le logo que j'aime le moins
This FOP label provides me with the information I need	Ce logo m'apporte l'information dont j'ai besoin
This FOP label is trustworthy	Ce logo m'inspire confiance
This FOP label provides reliable information	Ce logo permet d'avoir une information fiable
This FOP label is easy to identify	Ce logo est facile à repérer
This label is easy to understand	Ce logo est facile à comprendre
This FOP label is quick to process	Ce logo permet d'avoir une information rapide
This FOP label is too complex for understanding	Ce logo est trop compliqué à comprendre
This FOP label takes too long to understand	Ce logo est trop long à comprendre
This FOP label is guilt-laden	Ce logo est culpabilisant

Online supplementary material

Supplemental Table 2 responses to perception questions according clusters of preference for FOP nutrition labeling

Liking

	Nutriscore	MTL	SENS	mRIs	None
This FOP label is helpful to choose healthier products					
Nutriscore	74.32	13.93	19.21	7.81	4.84
SENS	9.91	5.45	65.23	4.96	1.54
MTL	9.78	75.12	8.65	7.54	3.2
mRIs	3.64	3.86	5.23	76.19	1.03
None	2.36	1.64	1.68	3.51	89.4
I want to see this FOP label on the front of packages					
Nutriscore	93.45	7.64	6.32	6.89	3.1
SENS	2.34	2.99	88.89	0.66	2.35
MTL	1.73	86.27	2.92	2.75	2.73
mRIs	0.82	2.21	0.59	86.66	0.81
None	1.66	0.89	1.28	3.04	91
This is my preferred FOP label					
Nutriscore	93.51	6.24	6.18	5.94	3.33
SENS	2.3	3.12	88.31	2.9	1.05
MTL	1.53	86.06	2.54	3.23	1.7
mRIs	0.33	1.84	0.42	81.23	0.47
None	2.33	2.74	2.55	6.7	93.45
This is the FOP label I appreciate the least					
Nutriscore	1.08	17.92	10.9	28.78	6.79
SENS	10.36	34.9	1.31	41.12	3.96
MTL	16.91	1.51	19.14	18.16	5.23
mRIs	66.88	39.88	61.86	5.85	10.78
None	4.77	5.78	6.78	6.09	73.24

Online supplementary material

Awareness and trustworthiness

	Nutriscore	MTL	SENS	mRIs	None
This FOP label provides me with the information I need					
Nutriscore	52.36	2.01	6.25	0.56	4.21
SENS	10.83	2.66	59.59	1.74	1.71
MTL	27.37	91.49	25.14	16.79	14.24
mRIs	7.78	3.58	6.87	78.6	3.66
None	1.67	0.25	2.16	2.31	76.17
This FOP label is trustworthy					
Nutriscore	79.33	4.82	9.29	3.48	3.67
SENS	4.55	1.79	74.04	0.98	1.5
MTL	7.98	87.15	8.04	1.98	1.21
mRIs	1.96	2.43	3.35	87.89	0.28
None	6.18	3.81	5.29	5.67	93.34
This FOP label provides reliable information					
Nutriscore	57.78	2.37	5.76	1.95	0.23
SENS	3.92	0.48	50.74	0.88	0.12
MTL	24.47	90.22	27.44	4.67	1.53
mRIs	6.54	3.18	9.22	87.05	2.36
None	7.29	3.75	6.84	5.45	95.75
This FOP label is easy to identify					
Nutriscore	93.08	53.69	19.15	45.28	20.69
SENS	6.03	15.02	79.02	11.56	6.82
MTL	0.34	29.44	0.99	4.83	1.41
mRIs	0.08	0.6	0.32	33.66	0.78
None	0.47	1.25	0.53	4.68	70.29

Online supplementary material

Perceived cognitive workload

	Nutriscore	MTL	SENS	mRIs	None
This label is easy to understand					
Nutriscore	77.11	45.5	17.55	33.92	19.4
SENS	20.75	30.45	80.77	20.47	18.54
MTL	1.41	22.27	1.58	9.16	4.46
mRIs	0.51	1.46	0.09	35.6	3.72
None	0.22	0.33	0	0.85	53.88
This FOP label is quick to process					
Nutriscore	92.72	55.07	23.2	47.31	30.42
SENS	6.18	18.75	75.65	13.43	11.67
MTL	0.62	25.17	0.75	7.31	5.22
mRIs	0.38	0.88	0.39	31.18	2.88
None	0.1	0.12	0.01	0.78	49.82
This FOP label is too complex for understanding					
Nutriscore	0.99	6.38	6.36	14.98	2.75
SENS	4.23	9.09	1.86	12.2	3.51
MTL	25.49	4.24	30.07	27.56	11.35
mRIs	57.73	46.53	50.78	10.9	21.55
None	11.56	33.77	10.92	34.35	60.84
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None	49.93	47.89	44.78	47.8	87.12

Online supplementary material

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **Page 4**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Page 4**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Page 6**
Objectives	3	State specific objectives, including any prespecified hypotheses **Page 7**
Methods		
Study design	4	Present key elements of study design early in the paper **Page 8**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Page 8**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants **Page 8-10**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Page 8-10**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Page 8-10**
Bias	9	Describe any efforts to address potential sources of bias **Page 10**
Study size	10	Explain how the study size was arrived at **Page 11**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Page 8-10**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **Page 10-11**
		(*b*) Describe any methods used to examine subgroups and interactions **Not applicable**
		(*c*) Explain how missing data were addressed **Page 10**
		(*d*) If applicable, describe analytical methods taking account of sampling strategy **Not Applicable**
		(*e*) Describe any sensitivity analyses **Not Applicable**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **Page 11**
		(b) Give reasons for non-participation at each stage **Page 11**
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **Page 12, Table 1**
		(b) Indicate number of participants with missing data for each variable of interest **Page 11**
Outcome data	15*	Report numbers of outcome events or summary measures **Page 12, Table 2**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included **Page 12-13, Tables**
		(*b*) Report category boundaries when continuous variables were categorized **Page 8-10, Tables**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **Not Applicable**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives **Page 13**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **Page 16**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Page 13-16**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Page 16**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **Page 3**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Perception of different formats of front-of-pack nutrition labels according to sociodemographic, lifestyle and dietary factors in a French population

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Complete List of Authors:	Julia, Chantal; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité; Hôpital Avicenne (AP-HP), Public Health Department Péneau, Sandrine; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité, Buscail, Camille; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité Gonzalez, Rebecca; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité Touvier, Mathilde; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité, Hercberg, Serge; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité; Hôpital Avicenne (AP-HP), Public Health Department Kesse-Guyot, Emmanuelle; Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle, Centre de Recherche en Epidémiologie et Statistiques, Inserm (U1153), Inra (U1125), Cnam, COMUE Sorbonne Paris Cité
Primary Subject Heading:	Health policy
Secondary Subject Heading:	Nutrition and metabolism, Epidemiology, Public health
Keywords:	public health policy, Front-of-pack nutrition labels, Perception

Perception of different formats of front-of-pack nutrition labels according to sociodemographic, lifestyle and dietary factors in a French population

Chantal Julia, senior lecturer[1,2], Sandrine Péneau, senior lecturer [1], Camille Buscail, resident[1], Rebecca Gonzales, Post-doc, Mathilde Touvier, research fellow [1], Serge Hercberg, professor[1,2], Emmanuelle Kesse-Guyot, director of research[1]

[1] Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle (EREN), Centre d'Epidemiologie et Biostatistiques Sorbonne Paris Cité (CRESS), Inserm U1153, Inra U1125, Cnam, COMUE Sorbonne-Paris-Cité, F-93017 Bobigny, France

[2] Département de Santé Publique, Hôpital Avicenne (AP-HP), F-93017 Bobigny, France

Corresponding author/reprints requests:

Chantal Julia c.julia@uren.smbh.univ-paris13.fr

Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle (EREN), Centre de Recherche en Epidémiologie et Biostatistiques, Inserm (U1153), Inra(U1125), Cnam, COMUE Sorbonne Paris Cité, F-93017 Bobigny, France.

74 rue Marcel Cachin F-93017 Bobigny Cedex. France.

+33 1 48 38 89 53
+33 1 48 38 89 31

Last name of authors: Julia, Péneau, Buscail, Gonzalez, Touvier, Hercberg, Kesse-Guyot

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Keywords: Front-of-pack nutrition labels; perception;

Abbreviations:

5-CNL: Five-colour nutrition label

FOP: Front-of-pack

FSA: Food Standards Agency

FSA-NPS DI : Food Standards Agency Nutrient Profiling System Dietary Index

NPS : Nutrient Profiling System

OfCom: Office of Communication

PNNS: Programme National Nutrition Santé

UK: United Kingdom

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CONFLICT OF INTEREST STATEMENT

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) No authors have support from any company for the submitted work; (2) All authors have no relationships with any company that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) All authors have no non-financial interests that may be relevant to the submitted work.

AUTHORSHIP CONTRIBUTION

CJ wrote the statistical analysis plan, analysed the data, and drafted and revised the paper. She is the guarantor. EKG participated in statistical analysis plan, analysed the data and critically revised the

paper for important intellectual content. MT CB SP RG analysed the data and critically revised the paper for important intellectual content. SH designed data collection tools, implemented the study, monitored data collection for the whole study, and critically revised the draft paper for important intellectual content. All authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. All authors have read and approved the final manuscript.

ETHICS

The NutriNet-Santé study is conducted in accordance with the Declaration of Helsinki, and all procedures have been approved by the Institutional Review Board of the French Institute for Health and Medical Research (0000388FWA00005831) and the *Commission Nationale de l'Informatique et des Libertés* (908450 and 909216). Electronic informed consent was obtained from all participants. The Nutrinet-santé study is registered under EudraCT registration number 2013-000929-31.

SOURCES OF SUPPORT

The NutriNet-Santé Study is supported by the French Ministry of Health, the Institut de Veille Sanitaire, the Institut National de la Santé et de la Recherche Médicale, the Institut National de la Recherche Agronomique, the Conservatoire National des Arts et Métiers, the Institut National de Prévention et d'Education pour la Santé and the Fondation pour la Recherche Médicale and Paris 13 University. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Study sponsors had no part in study design, collection, analysis, and interpretation of data and the writing of the article and the decision to submit it for publication. Researchers are independent from funders and sponsors. All researchers had access to all the data

TRANSPARENCY DECLARATION

Chantal Julia affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

DATA SHARING

All necessary information is available in the paper.

ABSTRACT

Objective: Four formats for a front-of-pack (FOP) nutrition label are currently considered in France: the Nutriscore (or 5-Colour Nutrition Label, developed by a public research team), the SENS (supported by retailers), multiple traffic lights (MTL, currently used in UK) and a modified version of the Reference Intakes (mRIs, supported by industry). Our objective was to investigate the perception of these FOP labels, according to sociodemographic, lifestyle and dietary factors.

Design: Cross-sectional study

Setting: Web-based French cohort

Main outcome measure: FOP labels perception

Participants: Participants in the NutriNet-Santé cohort received a specific questionnaire on the perceptions of the four label formats identified. Socio-demographic, lifestyle and dietary data (three 24h dietary records) were collected through self-administered questionnaires. Mutually exclusive clusters of FOP labels perception were identified through a multiple correspondence analysis followed by a hierarchical clustering procedure. Socio-demographic, lifestyle and dietary factors associated with the clusters were explored using multivariable multinomial logistic regression. All analyses were weighted according to 2009 French census data.

Results: Among the 21,702 participants in the study, the Nutriscore received the most important number of favourable responses on positive perception dimensions by participants, followed by MTL and SENS. The 5 identified clusters were characterized by marked preferences for Nutriscore (Cluster 1, 43.2% of participants, crude N=9,399), MTL (Cluster 2, 27.3%, crude N=6,163), SENS (Cluster 3, 17.05%, crude N=3,546), mRIs (Cluster 4, 7.31%, crude N=1,632) and none of the presented formats (Cluster 5, 5.10%, crude N=965). The Cluster 1 (Nutriscore) was associated with lower adherence to nutritional recommendations, while Cluster 2 (MTL) was associated with younger age and higher level of education.

Conclusion: The Nutriscore appears to have a wide reach in the population and to appeal to subjects with lower adherence to nutritional recommendations.

ARTICLE SUMMARY

- Cross-sectional study in a large population using validated data collection tools.
- Investigation of multiple dimensions of the perception of FOP labels (awareness, liking, perceived cognitive workload and trustworthiness), across various formats that are currently proposed in the French debate on FOP nutrition labelling.
- Identification of clustered preferences towards each type of format, and investigation of the association between socio-demographic and dietary factors with FOP label preferences
- Sample consisting of volunteer subjects included in a cohort study on nutrition, who are therefore more likely health conscious.
- Focus on the perception of FOP labels, and not on understanding or use of FOP labels in purchasing situations.

INTRODUCTION

Preventing non-communicable diseases has become a top priority for most industrialized countries, as they represent a major part of the burden of diseases (1). In France, cardiovascular diseases and cancers are the first causes of death, contributing each to approximately 30% of overall deaths every year (2). Diet has been recognized as a key modifiable factor which can influence – as preventive or risk factor – a wide range of non-communicable diseases, from cardiovascular disease to cancer, type 2 diabetes, metabolic syndrome or obesity (3-5). Given its potential lever for improvement of the health status of the population, most western countries have invested in state-level public health programs on nutrition, promoting healthy diets and physical activity (6-8). In France, the National Nutrition and Health Program (Programme National Nutrition et Santé, PNNS), launched in 2001 (9), sets a regulatory environment that promotes synergistic actions towards healthy eating and physical activity. The most pervasive actions that have been taken towards the population have consisted in the dissemination of nutrition recommendations in multimedia campaigns and booklets (10;11). Those recommendations act upon the nutrition knowledge of individuals, prompting them to modify their dietary behaviour by promoting consumption of some food groups (e.g. fruits and vegetables, whole-grain cereals, water) or limiting excessive intakes of others (saturated fat, added sugar and sodium) (12). Recently, novel complementary strategies have been put forward in a report to the French Minister of Health in 2014, highlighting the need for specific measures to modify the nutritional environment beyond the actions at the individual level (13). The report stressed in particular measures pertaining to nutrition labelling, in the form of a simplified front-of-pack (FOP) nutrition label, advertising regulation and nutritional taxation (13). Among the proposals of this report, the implementation of a FOP nutrition labelling system was considered as an effective opportunity by the Health Minister, and its principle was introduced in the 2016 French Health Law (14). Many countries have implemented FOP nutrition labels worldwide, either nutrient-specific, such as the 'Multiple Traffic Light' system in the UK (15) or summary measures, either simple – such as the Dutch 'Choices' logo (16) or the Nordic 'Green Keyhole' (17) – or graded – such as the 'Health Star Rating System' in New Zealand and Australia (18). Summary systems have been considered as more easily

understood and interpreted than nutrient-specific labels, in particular for vulnerable populations (19;20). Moreover, colour-coded systems are considered more favourably perceived than monochrome systems (20;21). The initial report to the French Health Minister contained a detailed proposal for a simple colour-coded and graded label, supported by scientific studies (22-34) and independent government agencies evaluations (35;36) in the form of the 5-Colour Nutrition Label (5-CNL). However, alternative proposals were put forward during the debate by industry and retailers, in a vast lobbying campaign (37). Finally, four alternative formats emerged in the debate: the Nutriscore (an updated graphical version of the 5-CNL), SENS (a summary, graded and colour-coded label, developed and promoted by retailers), Multiple Traffic Lights (MTL, nutrient-specific and colour-coded label, currently used in the United Kingdom, UK) and a modified version of the Reference Intakes (mRIs, a nutrient-specific and monochrome label promoted by industry) (**Figure 1**). However, to date, no scientific study has directly compared the perception of the four proposed formats. Some studies tend to indicate that the 5-CNL would be more favourably perceived than MTL or RIs (25)and that it may help consumers identifying (24;25) and purchasing healthier foods (26;34) but no data has been published on the mRIs or the SENS formats.

The objective of the present study was therefore to investigate the perception of the four formats that have been put forward in France in the debate on FOP nutrition labelling, in a comparative design carried out in the NutriNet-Santé cohort.

MATERIAL AND METHODS

Population

Participants were selected from the NutriNet-Santé cohort. Briefly, the NutriNet-santé study is a prospective cohort study set in France in which inclusion and follow-up of volunteer participants are entirely performed on the Internet (38). The main objectives of the NutriNet-santé study are: 1) to investigate the relationship between nutrition and health outcomes; and 2) to investigate the determinants of dietary patterns and nutritional status. Inclusion in the study began in May, 2009, and is still ongoing. Volunteer participants aged >18 years-old subscribe to the study, and are included

when they have completed a set of questionnaires assessing: diet (through repeated 24h dietary records), physical activity, anthropometry, lifestyle and socio-economic conditions and health status. These five types of questionnaires are repeated yearly and have been validated against traditional assessment methods (paper or interview by dieticians) (39-41). Once the subjects are included in the cohort, they receive monthly web-questionnaires pertaining to various aspects of dietary behaviour, physical activity and health, which are optional, and graded according to their relative importance for research. Participants do not receive any form of incentive or compensation to participate in the online surveys. One of these questionnaires pertained to the perception of the various FOP labelling systems that have been proposed in the French context and was sent to all participants in the cohort in June 2016.

Detailed information on the NutriNet-Santé study can be found elsewhere (38).

Ethics

The NutriNet-Santé study is conducted in accordance with the Declaration of Helsinki, and all procedures have been approved by the Institutional Review Board of the French Institute for Health and Medical Research (0000388FWA00005831) and the *Commission Nationale de l'Informatique et des Libertés* (908450 and 909216). Electronic informed consent was obtained from all participants. The NutriNet-Santé study is registered under EudraCT registration number 2013-000929-31.

Perception of FOP labels

A specific questionnaire was develop using survey items from previously published research to investigate participants' perceptions of the four FOP labelling formats that are currently being debated in France (25;42). The questionnaire also included other dimensions of FOP nutrition labelling evaluation (objective understanding and legitimacy), which were not used in this study. A brief presentation of the four FOP labels was provided for the participants at the beginning of the questionnaire on the perceptions of FOP labels. The presentation made no mention of the origin or support by researchers or industry of each format, in order not to influence the participants based on this information.

Briefly, the Nutriscore, developed by the Nutritional Epidemiology Research Team (Equipe de Recherche en Epidémiologie Nutritionnelle, authors of this paper, EREN) scientific research team, and based on the British Food Standards Agency nutrient profiling system and adapted for the French context by the High Council for Public Health (36) presents for each food or beverage the overall nutritional quality on a 5-point colour-coded scale from Green to Red (**Figure 1**). SENS, supported by retailers, is based on a nutrient profiling system developed by a research team, and presents for each food or beverage a recommended frequency of consumption, with a 4 points colour-coded scale (Green, Blue, Orange and Purple) (**Figure 1**). MTL, implemented in Great Britain since 2005 presents the numeric values of the contribution of a portion of the food to the intakes in a balanced diet (in grams and percentage of reference intakes, corresponding to the reference intakes label) for energy, fats, saturated fats, sugar and sodium, with a colour-coding (Green, Amber and Red) for each of these components of the food (**Figure 1**). The Modified Reference Intakes (mRIs) present the numeric values of the reference intakes, in both grams and percentage of reference intakes, with bars varying in height depending on the amount of the component in the food (**Figure 1**).

Overall, 13 questions were asked on various aspects of liking (e.g. “This is my preferred FOP label”), trustworthiness (e.g. “This FOP label provides reliable information”), awareness (e.g. “This FOP label is easy to identify”) and perceived cognitive workload (e.g. “This label is too complex for understanding”) (**see Supplemental table 1**). For each question, subjects were asked to select among the four formats the label that best corresponded to them. The participants could also select that ‘none’ of the proposed labels corresponded to his/her perception.

Socio-demographic and lifestyle data

Socio-demographic and lifestyle data were collected through self-administered questionnaires and included age, sex, education (no diploma and up to secondary education, University ≤ 2 years, University > 2 years), marital status (in couple, single/divorced/widowed), income per household unit (43) (<1200/month, 1200 – 1800, 1800 – 2700, ≥ 2700 €/month) and smoking status (current smoker, former smoker and never smoker). Physical activity was computed using self-declared data from the validated International Physical Activity Questionnaire (low, moderate and high physical activity

levels) (44). The data collected in the questionnaire closest in time to the questionnaire on the perceptions of FOP labels were taken into account for the analyses.

Dietary data

Dietary data were derived from three repeated 24-hour records randomly distributed in a two-week period, with two week days and one week-end day. Food consumption was weighted according to the day of the week of each record. The participants are asked to estimate the portion size for each reported food and beverage item using validated photographs (45). Nutrient intake was computed using a published food composition database reflecting foods usually consumed in the French diet (46). Under- reporters for energy intake were identified using Goldberg/Black's method and were excluded (47). The dietary data from the 24h dietary record in the NutriNet-Sante study have been validated against interviewer-led dietary recalls conducted by trained dietitians, and against biomarkers of nutritional status (40;48;49).

Statistical analysis

For the present study, all participants who had completed the questionnaire on the perception of FOP labels, and having completed information on all covariates were eligible to the present study. Subjects were excluded if they stated that they never engaged in grocery shopping. The records and questionnaires closest to the questionnaire on the perceptions of FOP labels were taken into account for the analyses.

Weighting of the data

All data were weighted using the SAS CALMAR (CALage sur MARges) macro developed in France by the Institute of National Statistics (INSEE) to weight survey data to be representative of the French census population (50). Data used for weighting were sex, age and educational level.

Adherence to dietary recommendations

Adherence to French dietary recommendations was assessed using a modified version of the PNNS guidelines score (namely, the "*Programme National Nutrition Santé"*-guideline score, PNNS-GS), taking into account only dietary recommendations. The PNNS-GS development, including food

groupings, serving sizes, scoring, cut-off and penalties, has been previously described in detail (51). Briefly, this 15-point score is based on French national guidelines and includes 13 components. The eight components referring to food serving recommendations and four components referring to moderation in consumption were included in the modified version of the PNNS-GS (mPNNS-GS) (52). The last component focusing on adherence to physical activity recommendations was not taken into account.

A penalty for overconsumption was assigned to individuals with energy intakes higher than estimated energy expenditure (51). Age and self-reported weight and height at inclusion were used to estimate Schofield's basal metabolic rate (BMR) (53). Energy expenditures were estimated using BMR and physical activity level. In case of energy intake greater than 5% over the estimated energy expenditure, an identical part was subtracted from the score. Quartiles of mPNNS-GS were computed and used throughout the analyses.

Dietary clusters identification

The responses from the 13 "perception" questions were used in a multiple correspondence analysis, which yielded 4 dimensions of FOP labelling perception. The dimensions were selected based on their adjusted inertia (respectively 33.6%, 23.0%, 18.4% and 17.2% for a total of 92.3%). The selected dimensions were used as input variables in a two-ways clustering procedure based on hierarchical and K-means methods (SAS CLUSTER and FASCLUST procedures). The plot of semi-partial R^2, the semi-partial T^2 and the Cubic Clustering Criterion (CCC) by the number of clusters were used to identify the optimal number of clusters.

Statistical analysis

All analyses were weighted according to the CALMAR macro, except the clustering procedure for which no weighting option is available. The responses to each of the 13 questions were mapped across clusters, in order to identify the FOP perception characteristics of each cluster. Socio-demographic, lifestyle and dietary variables were mutually adjusted against clusters in a multivariable multinomial

regression. Adjusted-percentages for each socio-demographic, lifestyle and dietary characteristic were extracted from this procedure across clusters.

All tests were two-sided and a P value <0.01 was considered significant, given the high number of statistical tests performed and the large sample size. Statistical analyses were performed using SAS Software (version 9.3, SAS Institute Inc, Cary, NC, USA).

RESULTS

Overall, 38,604 subjects completed the questionnaire on the perceptions of FOP labels. Among these, 714 (1.85%) were excluded because they never engaged in grocery shopping. Among the 37,890 remaining subjects, 16,188 (42.72%) were excluded for incomplete data on covariates (the vast majority of which (N=13,066, 80.71% of excluded subjects) for incomplete data on mPNNS-GS computation, which requires the presence of three 24h records, frequency questionnaire on alcohol consumption and frequency of seafood consumption, leading to an overall sample of 21,702 participants for analysis (e.g. 56.22%).

Characteristics of the crude and weighted sample are presented in **Table 1**. The crude sample exhibited a higher percentage of females (73.42%), older subjects (68.36% were ≥ 50 years-old), educated (37.54% had above 2 years of university training) and with high incomes (38.49% had incomes >2700€/month).

Overall, the Nutriscore was the label receiving the most important number of favourable responses on positive perception dimensions by participants, followed by MTL and SENS (43.79% of participants considered the Nutriscore as their preferred FOP label, followed by 24.92% for MTL and 17.17% for SENS) (**Table 2**). Conversely, RIs yielded the highest number of responses on negative dimensions of perception (complexity and time processing). A majority of participants considered that none of the proposed labels were guilt-laden (50.23%), followed by SENS (21.19%)

The clustering procedure resulted in the identification of 5 mutually exclusive groups of subjects according to their perception of FOP nutrition labels. Clusters represented 43.23% (crude N=9,399), 27.31% (crude N=6,163), 17.05% (crude N=3,546), 7.31% (crude N=1,632) and 5.10% (crude N=965)

of participants, respectively. The mapping of perception responses across clusters showed that each cluster was characterized by a marked preference for one of the proposed FOP nutrition label formats: Cluster 1 displayed a marked preference for the Nutriscore, Cluster 2 for the MTL, Cluster 3 for the SENS, Cluster 4 for the RIs and Cluster 5 for none of the presented labels (**Figure 2**). Therefore, clusters were termed according to their label preference. These preferences across cluster were particularly prominent for the following aspects: label wanted on the front of the packages (>85% for each specific FOP label in their respective cluster), preferred label (>80% for each specific label in their respective cluster), label allowing to choose healthier products (>65% for each specific label in their respective cluster), trustworthiness (>74% for each specific label in their respective cluster) (**Figure 2**). However, for some dimensions of perception, responses were somewhat less marked for each specific FOP label, and more concurrent across clusters. For example, >23% of participants in all clusters considered that the Nutriscore was quick to process, >19% considered it easy to identify, and >17% considered it easy to understand (**Figure 2**). Conversely, >20% of participants in all clusters considered the mRIs to be too complex for understanding (except in its own where it obtained 10.90% of opinions), >19% considered it too long to understand (except in its own cluster, with 12.73% of opinions), and was considered as the least appreciated FOP nutrition label for 66.88% of subjects in the Cluster Nutriscore, 61.86% of subjects in the Cluster SENS, 39.88% of subjects in the Cluster MTL and 10.78% of subjects in the Cluster None (**Figure 2**). Finally, participants considered that none of the presented labels was guilt-laden: 87.12% of Cluster None, 49.93% of Cluster Nutriscore, 47.89% of Cluster MTL, 47.80% of Cluster mRIs and 44.78% of Cluster SENS (**Figure 2**).

Multivariable adjusted socio-demographic characteristics according to specific clusters are shown in **Table 3**. Less educated subjects were more frequent in Cluster None and Cluster mRIs and highly educated subjects in Cluster MTL (**Table 2**). Smokers were more likely in Cluster None, while never smokers were more likely in Cluster Nutriscore. Subjects with low physical activity were more likely in Cluster SENS and Cluster Nutriscore (**Table 2**). Finally, subjects with lower adherence to dietary recommendations (Quartile 1 of mPNNS-GS) were more likely in Cluster None and Cluster

Nutriscore while subjects with high adherence to dietary recommendations (Quartile 4 of mPNNS-GS) were more likely in Cluster mRIs and Cluster MTL (**Table 2**).

DISCUSSION

Our study showed that the perception of FOP labels can be clustered according to consistent preferences for specific formats. Among the proposed labels in the current French debate, the Nutriscore appeared to be the most preferred format, followed by MTL. Moreover, though each cluster presented marked preferences for one type of format or another, the Nutriscore appeared to reach to participants beyond its specific cluster, as it was considered easy to identify and understand by a significant number of participants in other clusters. Finally, socio-demographic characteristics appeared to be associated with each cluster, with a specific cluster (Cluster 5, None), concentrating high percentages of subjects presenting disadvantaged socio-demographic characteristics (lower levels of education) and lifestyle risks (smoking, low level of physical activity and low adherence to dietary recommendations).

Compared to a previous study conducted in early 2015 using a similar methodology and among participants in the same cohort study, the results of the present analyses show that the reach of the Nutriscore has somewhat broadened since then (25). The Nutriscore appeared to have a wide reach in the population, and to appeal to subjects with lower adherence to dietary recommendations. This result shows that the Nutriscore may be an effective complementary strategy to current public health nutrition policies, which promote healthy eating through widely disseminated nutritional recommendations (54). Though this strategy has led to an increase in the knowledge of nutritional recommendations, consumers somehow struggle to translate such advice into action (55;56). Disseminated nutrition information is suggested to appeal more to those already having the capacity to implement nutritional knowledge (through higher education or income), and may lead to an increase in social disparities in health (57;58). Therefore, the fact that the Nutriscore appears to appeal to subjects with low adherence to nutrition recommendations may be a key element to help translating nutritional recommendations into practice, in particular for those with low nutritional knowledge.

The MTL appeared as the second preferred FOP label in the population, particularly in younger subjects, with university education and lower incomes. Moreover it was considered to be providing reliable and useful information beyond its own cluster. The fact that direct numeric information on nutrient content (such as the information provided by mRIs) received a much lower support in the population shows that the appeal of the MTL is very probably associated with the colour feature of this FOP label (59), as multiple numeric information are typically considered difficult to understand (60). Indeed, compared to mRIs, the MTL only adds an interpretation of the level of nutrients using a colour-coding. However, the interpretation of the colour-coding has appeared to be challenging in certain populations (59). Indeed, MTL is a nutrient-specific FOP label, giving individual information for energy and four nutrients (sugars, fat, saturated fat and salt). Multiple nutrient-related information implies first that consumers are able to identify the nutrients that are referred to, and second, that they are able to prioritize the information provided for each nutrient (42;61). Indeed, MTL can lead to conflicting choice options: for example, the comparison between two products, with the same number of nutrients coded in 'red', but not for the same nutrients (e.g. one with a 'red' code for sugar and the other for saturated fatty acids) implies for the consumer to be able to single out one of the nutrients in order to make a choice (21). These characteristics of the label may in part explain the fact that the MTL appeared to appeal more particularly to young, educated subjects with a high level of adherence to nutritional recommendations. This more favourable perception among these participants may stem from their higher nutritional knowledge, which allows them to better interpret the label and act upon it in purchasing situations (21;60). However, this specific reach in terms of population might also lead to widen inequalities in health and nutrition if implemented in the overall population (62).

The SENS system was the preferred system for 17% of the population, more particularly in households with children. The graphical system the SENS originated from was developed by a marketing team from a retailer in September 2014, and received later support from the French retailers' federation (37). As for Nutriscore or MTL, it is based on colour coding (though not based on the polychromatic Green-Red scale), with the addition of recommended frequencies of consumption for each level of the label. This latter feature may in part explain the higher appeal of the SENS system

on participants with children, as it gives a more specific guidance for consumption, which can be used for children. However, these specific consumption frequencies for each level of the label could also be interpreted as an oversimplification and a form of paternalism for many consumers (63). This may be one of the reasons the SENS label was considered as a guilt-laden label for 21.2% of the population.

Moreover, though Nutriscore and MTL rely on the well-known polychromatic scale from green to red (corresponding to recognized signals), which are easier to interpret, the SENS colour-coding does not refer directly to any known colour scale (its levels are Green-Blue-Orange-Purple). Colours are considered helpful to generally increase the salience of a FOP label, however, studies that have shown a specific advantage of colour-coding have used readily interpretative colour-coding (63-66). In the study by Bialkova et al., which used polychromatic RIs, but with no readily-interpretative colours (yellow, orange, purple, blue), the polychromatic RIs indeed had lower performance than monochromatic RIs (64). Therefore, beyond preference only, the use of highly interpretable colours (e.g. 'Green' and 'Red') in a FOP labelling system might be an important feature of a colour coding.

Finally, our study shows that a portion of the population appeared to disregard or even reject FOP nutrition labels entirely. Indeed, participants in Cluster 5 (None, corresponding to 5.1% of the population) consistently responded 'None' for all dimensions of perception that were investigated. Moreover, the socio-demographic characteristics of this specific population suggested that they may in fact be more vulnerable and more at nutritional risk than the rest of the population. Indeed, this cluster included more specifically older participants, subjects with lower educational levels, current smokers and subjects with lower adherence to nutritional recommendations. This result is in line with a study in Australia showing that males and subjects with lower socio-economic status were more likely to report no preference for a FOP label (67). These results also pose a challenge to the design of efficient public health policies, as some of the subjects who would certainly benefit from them appear to reject them. Novel and targeted interventions in public health nutrition should therefore be devised to appeal to this vulnerable population to entice them towards healthier diets, taking into account the broader environment related to risk behaviours (68). Alternatively, policies targeting the environment, and not

depending on individual choices, such as the reformulation of existing products, may have an indirect impact on these populations (69).

Strengths of our study include its large sample size, and the use of validated dietary collection data, using repeated dietary records (40). Moreover, we were able to investigate multiple dimensions of the perception of FOP labels (awareness, liking, perceived cognitive workload and trustworthiness), across various formats that are currently proposed in the French debate on FOP nutrition labelling. Finally, we were able to identify clustered preferences towards each type of format, and relate them to socio-demographic and dietary factors, which highly contributed to the interpretation of such preferences in a public health perspective.

Our study is subject to some limitations. First, our sample consists of volunteer subjects included in a cohort study on nutrition, who are therefore more likely health conscious. However, our data shows a wide variety of dietary profiles, somewhat lessening the importance of this bias. Moreover, the use of weighting partially controlled for the selection bias of our study population (70). Second, our study focused on the perception of FOP labels, and not on understanding or use of FOP labels in purchasing situations. However, following the theoretical framework for the use of FOP nutrition labels, favourable perception is a crucial pre-requisite for the efficiency of a given label (71;72). Third, the participants in the NutriNet-Santé study had already been involved in a previous survey on the perception of various FOP nutrition labels (25). However, the formats presented in the two versions of the questionnaire were somewhat different, and the delay between the two questionnaires of more than a year, therefore limiting the familiarity of the participants with the FOP nutrition labels formats displayed in this study. However, the participants were aware of FOP nutrition labelling, which could have affected their responses. Finally, the measures used in this study were not thoroughly validated but based on scientific literature. They derived from previously published work which took into account the literature on the perception of FOP nutrition labelling (42;61;73).

To conclude, FOP nutrition labels could be useful strategies to tackle social inequalities in nutrition and health, provided that the graphical format that is selected has a wide reach in the population. This

is all the more important that subjects who are more concerned about their diet (and more likely to have a healthier diet), are also more likely to use a nutrition label when grocery shopping (20). As such, the Nutriscore, which has a favourable perception among subjects with low adherence to nutritional recommendations, may be a helpful strategy to lead them towards healthier diets.

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FIGURE LEGENDS

Figure 1: Formats proposed for a front-of-pack nutrition label in France.

Caption:

Nutriscore developed by the EREN research team, is based on the British Food Standards Agency nutrient profiling system and presents for each food or beverage the overall nutritional quality on a five-point colour-code scale from Green to Red.

SENS, supported by retailers, is based on a nutrient profiling system developed by a research team, and presents for each food or beverage a recommended frequency of consumption, with a four points colour-coded scale (Green, Blue, Orange, Purple)

Multiple Traffic Lights, supported by industry, and implemented in Great Britain since 2005 presents the numeric values of the contribution of a portion of the food to the intakes in a balanced diet (in grams and percentage of reference intakes, corresponding to the reference intakes label, RI) for energy, fats, saturated fats, sugar and sodium, with a colour-coding (Green, Amber and Red) for each of these components of the food

Modified Reference Intakes (mRIs) present the numeric values of the reference intakes, in both grams and percentage of reference intakes, with bars varying in height depending on the amount of the component in the food.

Figure 2: Responses to each of the dimensions of perception in the various clusters

Caption: Each circle represents a cluster, each response to a dimension is scaled within the cluster. Positive dimensions are situated on the right hand side of the figure, while negative dimensions are situated on the left hand side of the figure

Table 1 Characteristics of the study population, crude and after weighting

		Crude		Weighted
		n	%	%
Sex				
	Men	5768	26.58	39.97
	Women	15934	73.42	60.03
Age				
	18-29 years-old	968	4.46	12.28
	30-49 years-old	5900	27.19	31.05
	50-64 years-old	7899	36.40	29.39
	≥ 65 years old	6935	31.96	27.28
Educational level				
	Up to secondary	6804	31.35	70.54
	University, up to two years	6750	31.10	13.86
	University, ≥ 3 years	8148	37.54	15.60
Income per consumption unit				
	<1200/month	2068	9.53	20.28
	[1200 - 1800[€/month	4766	21.96	30.24
	[1800 - 2700[€/month	6514	30.02	28.67
	≥ 2700 €/month	8354	38.49	20.81
Household composition				
	Adults only	17118	78.88	78.05
	Adults and children	4584	21.12	21.95
Smoking status				
	Current smoker	1923	8.86	10.16
	Former smoker	8710	40.13	39.81
	Never smoker	11069	51.00	50.03
Physical activity level				
	High	8007	36.90	39.01
	Moderate	9128	42.06	37.28
	Low	4567	21.04	23.72
mPNNS-GS				
	Quartile 1	5425	25.00	23.70
	Quartile 2	5582	25.72	23.86
	Quartile 3	5933	27.34	26.20
	Quartile 4	4762	21.94	26.24

Weighting was obtained using the SAS CALMAR Macro

Online Supplemental material

Table 2 Crude percentage of responses to the dimensions of perception of FOP labels

	Nutriscore	MTL	SENS	mRIs	None
This FOP label is helpful to choose healthier products	40.02	26.93	17.33	9.14	6.57
I want to see this FOP label on the front of packages	44.22	25.15	17.15	7.43	6.05
This is my preferred FOP label	43.79	24.92	17.17	6.68	7.45
This FOP label provides me with the information I need	24.51	43.06	15.78	11.44	5.21
This FOP label is trustworthy	37.64	28.83	15.23	8.52	9.79
This FOP label provides reliable information	26.76	40.32	10.55	11.75	10.62
This FOP label is easy to identify	62.53	8.78	21.37	2.75	4.56
This label is easy to understand	52.22	7.86	33.5	3.43	2.99
This FOP label is quick to process	64.09	8.07	22.27	2.9	2.68
This FOP label is too complex for understanding	4.49	19.9	5.7	48.22	21.7
This FOP label takes too long to understand	2.52	25.45	2.86	50.81	18.36
This is the FOP label I appreciate the least	9.67	12.58	17.44	51.33	8.98
This FOP label is guilt-laden	12.42	9.32	21.19	6.83	50.23

Online Supplemental material

Table 3 Multivariable adjusted socio-demographic, lifestyle and dietary characteristics according to the various clusters of preference for FOP nutrition labeling

		Nutriscore	MTL	SENS	mRIs	None	*P*
		43.23	27.31	17.05	7.31	5.10	
Sex							*<0,0001*
	Men	**41.88**	37.23	37.48	**35.67**	40.14	
	Women	58.12	62.77	62.52	64.33	59.86	
Age							*<0,0001*
	18-29 years-old	11.11	**13.90**	11.06	11.82	3.93	
	30-49 years-old	64.66	68.43	67.53	66.86	64.92	
	50-64 years-old	21.40	15.86	19.04	18.05	25.76	
	≥ 65 years old	2.84	1.81	2.37	3.27	**5.40**	
Educational level							*<0,0001*
	Up to secondary	72.64	67.59	72.05	77.71	**77.84**	
	University, up to two years	15.26	16.81	15.72	12.79	12.21	
	University, ≥ 3 years	12.09	**15.61**	12.23	9.50	9.95	
Income per consumption unit							*<0,0001*
	<1200/month	14.57	**20.07**	16.36	17.17	13.95	
	[1200 - 1800[€/month	32.61	31.47	35.57	35.71	36.83	
	[1800 - 2700[€/month	30.96	29.29	29.41	29.17	30.45	
	≥ 2700 €/month	**21.85**	19.16	18.66	17.96	18.77	
Household composition							*<0,0001*
	Adults only	87.76	88.57	86.99	88.60	**90.35**	
	Adults and children	12.24	11.43	**13.01**	11.40	9.65	
Smoking status							*<0,0001*
	Current smoker	10.91	11.33	9.94	9.35	**15.59**	
	Former smoker	31.74	34.95	34.21	35.63	32.69	
	Never smoker	**57.35**	53.72	55.85	55.02	51.73	
Physical activity level							*<0,0001*
	High	31.73	34.19	31.12	**35.93**	29.38	
	Moderate	40.97	44.91	41.20	41.62	43.90	
	Low	27.30	20.90	**27.68**	22.44	26.71	
mPNNS-GS							*<0,0001*
	Quartile 1	28.28	25.09	23.90	21.63	**32.47**	
	Quartile 2	25.90	22.09	26.67	20.08	30.08	
	Quartile 3	26.86	28.44	26.96	30.87	21.86	
	Quartile 4	18.96	24.37	22.47	27.42	**15.59**	

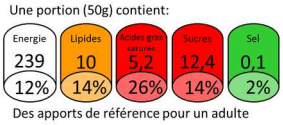
Mutually adjusted percentages obtained with multinomial regression

Nutriscore

SENS

Modified Reference Intakes

Multiple Traffic Lights



Formats proposed for a front-of-pack nutrition label in France.
Caption:
Nutriscore developed by the EREN research team, is based on the British Food Standards Agency nutrient profiling system and presents for each food or beverage the overall nutritional quality on a five-point colour-code scale from Green to Red.
SENS, supported by retailers, is based on a nutrient profiling system developed by a research team, and presents for each food or beverage a recommended frequency of consumption, with a four points colour-coded scale (Green, Blue, Orange, Purple)
Multiple Traffic Lights, supported by industry, and implemented in Great Britain since 2005 presents the numeric values of the contribution of a portion of the food to the intakes in a balanced diet (in grams and percentage of reference intakes, corresponding to the reference intakes label, RI) for energy, fats, saturated fats, sugar and sodium, with a colour-coding (Green, Amber and Red) for each of these components of the food
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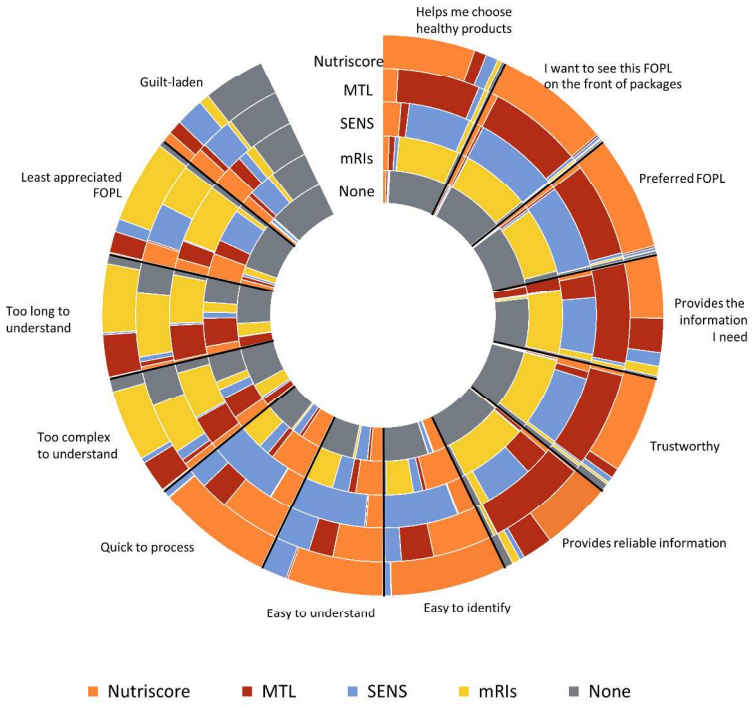
254x190mm (300 x 300 DPI)



Responses to each of the dimensions of perception in the various clusters
Caption: Each circle represents a cluster, each response to a dimension is scaled within the cluster. Positive dimensions are situated on the right hand side of the figure, while negative dimensions are situated on the left hand side of the figure

254x190mm (300 x 300 DPI)

Online supplementary material

Supplemental Table 1 Questionnaire used to assess perception of the various FOP nutrition labels (French version and English translation)

Question (English Translation)	Question (Original question in French)
This FOP label is helpful to choose healthier products	Ce logo aide à choisir des produits meilleurs pour la santé
I want to see this FOP label on the front of packages	Je veux qu'il soit présent sur les emballages
This is my preferred FOP label	C'est mon logo préféré
This is the FOP label I appreciate the least	C'est le logo que j'aime le moins
This FOP label provides me with the information I need	Ce logo m'apporte l'information dont j'ai besoin
This FOP label is trustworthy	Ce logo m'inspire confiance
This FOP label provides reliable information	Ce logo permet d'avoir une information fiable
This FOP label is easy to identify	Ce logo est facile à repérer
This label is easy to understand	Ce logo est facile à comprendre
This FOP label is quick to process	Ce logo permet d'avoir une information rapide
This FOP label is too complex for understanding	Ce logo est trop compliqué à comprendre
This FOP label takes too long to understand	Ce logo est trop long à comprendre
This FOP label is guilt-laden	Ce logo est culpabilisant

Online supplementary material

Supplemental Table 2 responses to perception questions according clusters of preference for FOP nutrition labeling

Liking

	Nutriscore	MTL	SENS	mRIs	None
This FOP label is helpful to choose healthier products					
Nutriscore	74.32	13.93	19.21	7.81	4.84
SENS	9.91	5.45	65.23	4.96	1.54
MTL	9.78	75.12	8.65	7.54	3.2
mRIs	3.64	3.86	5.23	76.19	1.03
None	2.36	1.64	1.68	3.51	89.4
I want to see this FOP label on the front of packages					
Nutriscore	93.45	7.64	6.32	6.89	3.1
SENS	2.34	2.99	88.89	0.66	2.35
MTL	1.73	86.27	2.92	2.75	2.73
mRIs	0.82	2.21	0.59	86.66	0.81
None	1.66	0.89	1.28	3.04	91
This is my preferred FOP label					
Nutriscore	93.51	6.24	6.18	5.94	3.33
SENS	2.3	3.12	88.31	2.9	1.05
MTL	1.53	86.06	2.54	3.23	1.7
mRIs	0.33	1.84	0.42	81.23	0.47
None	2.33	2.74	2.55	6.7	93.45
This is the FOP label I appreciate the least					
Nutriscore	1.08	17.92	10.9	28.78	6.79
SENS	10.36	34.9	1.31	41.12	3.96
MTL	16.91	1.51	19.14	18.16	5.23
mRIs	66.88	39.88	61.86	5.85	10.78
None	4.77	5.78	6.78	6.09	73.24

Online supplementary material

Awareness and trustworthiness

	Nutriscore	MTL	SENS	mRIs	None
This FOP label provides me with the information I need					
Nutriscore	52.36	2.01	6.25	0.56	4.21
SENS	10.83	2.66	59.59	1.74	1.71
MTL	27.37	91.49	25.14	16.79	14.24
mRIs	7.78	3.58	6.87	78.6	3.66
None	1.67	0.25	2.16	2.31	76.17
This FOP label is trustworthy					
Nutriscore	79.33	4.82	9.29	3.48	3.67
SENS	4.55	1.79	74.04	0.98	1.5
MTL	7.98	87.15	8.04	1.98	1.21
mRIs	1.96	2.43	3.35	87.89	0.28
None	6.18	3.81	5.29	5.67	93.34
This FOP label provides reliable information					
Nutriscore	57.78	2.37	5.76	1.95	0.23
SENS	3.92	0.48	50.74	0.88	0.12
MTL	24.47	90.22	27.44	4.67	1.53
mRIs	6.54	3.18	9.22	87.05	2.36
None	7.29	3.75	6.84	5.45	95.75
This FOP label is easy to identify					
Nutriscore	93.08	53.69	19.15	45.28	20.69
SENS	6.03	15.02	79.02	11.56	6.82
MTL	0.34	29.44	0.99	4.83	1.41
mRIs	0.08	0.6	0.32	33.66	0.78
None	0.47	1.25	0.53	4.68	70.29

Online supplementary material

Perceived cognitive workload

	Nutriscore	MTL	SENS	mRIs	None
This label is easy to understand					
Nutriscore	77.11	45.5	17.55	33.92	19.4
SENS	20.75	30.45	80.77	20.47	18.54
MTL	1.41	22.27	1.58	9.16	4.46
mRIs	0.51	1.46	0.09	35.6	3.72
None	0.22	0.33	0	0.85	53.88
This FOP label is quick to process					
Nutriscore	92.72	55.07	23.2	47.31	30.42
SENS	6.18	18.75	75.65	13.43	11.67
MTL	0.62	25.17	0.75	7.31	5.22
mRIs	0.38	0.88	0.39	31.18	2.88
None	0.1	0.12	0.01	0.78	49.82
This FOP label is too complex for understanding					
Nutriscore	0.99	6.38	6.36	14.98	2.75
SENS	4.23	9.09	1.86	12.2	3.51
MTL	25.49	4.24	30.07	27.56	11.35
mRIs	57.73	46.53	50.78	10.9	21.55
None	11.56	33.77	10.92	34.35	60.84
This FOP label takes too long to understand					
Nutriscore	0.77	3.45	2.37	11.12	0.65
SENS	1.57	4.47	2.19	7.43	0.81
MTL	33.71	4.33	36.95	35.12	16.19
mRIs	55.76	58.12	52.13	12.73	19.83
None	8.19	29.63	6.36	33.6	62.51
This FOP label is guilt-laden					
Nutriscore	8.33	14.8	21.33	12.13	4.97
SENS	22.37	27.72	9.68	28.3	4.59
MTL	11.15	5.87	14.04	5.84	1.59
mRIs	8.23	3.73	10.16	5.93	1.73
None	49.93	47.89	44.78	47.8	87.12

Online supplementary material

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **Page 4**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Page 4**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Page 6**
Objectives	3	State specific objectives, including any prespecified hypotheses **Page 7**
Methods		
Study design	4	Present key elements of study design early in the paper **Page 8**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Page 8**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants **Page 8-10**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Page 8-10**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Page 8-10**
Bias	9	Describe any efforts to address potential sources of bias **Page 10**
Study size	10	Explain how the study size was arrived at **Page 11**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Page 8-10**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **Page 10-11**
		(*b*) Describe any methods used to examine subgroups and interactions **Not applicable**
		(*c*) Explain how missing data were addressed **Page 10**
		(*d*) If applicable, describe analytical methods taking account of sampling strategy **Not Applicable**
		(*e*) Describe any sensitivity analyses **Not Applicable**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **Page 11**
		(b) Give reasons for non-participation at each stage **Page 11**
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **Page 12, Table 1**
		(b) Indicate number of participants with missing data for each variable of interest **Page 11**
Outcome data	15*	Report numbers of outcome events or summary measures **Page 12, Table 2**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included **Page 12-13, Tables**
		(*b*) Report category boundaries when continuous variables were categorized **Page 8-10, Tables**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **Not Applicable**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives **Page 13**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **Page 16**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Page 13-16**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Page 16**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **Page 3**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

BMJ Open

Perception of different formats of front-of-pack nutrition labels according to sociodemographic, lifestyle and dietary factors in a French population : cross-sectional study among the NutriNet-Santé cohort participants.

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Primary Subject Heading:	Health policy
Secondary Subject Heading:	Nutrition and metabolism, Epidemiology, Public health
Keywords:	public health policy, Front-of-pack nutrition labels, Perception

Perception of different formats of front-of-pack nutrition labels according to sociodemographic, lifestyle and dietary factors in a French population : cross-sectional study among the NutriNet-Santé cohort participants.

Chantal Julia, senior lecturer[1,2], Sandrine Péneau, senior lecturer [1], Camille Buscail, resident[1], Rebeca Gonzalez, Post-doc, Mathilde Touvier, research fellow [1], Serge Hercberg, professor[1,2], Emmanuelle Kesse-Guyot, director of research[1]

[1] Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle (EREN), Centre d'Epidemiologie et Biostatistiques Sorbonne Paris Cité (CRESS), Inserm U1153, Inra U1125, Cnam, COMUE Sorbonne-Paris-Cité, F-93017 Bobigny, France

[2] Département de Santé Publique, Hôpital Avicenne (AP-HP), F-93017 Bobigny, France

Corresponding author/reprints requests:

Chantal Julia c.julia@uren.smbh.univ-paris13.fr

Université Paris 13, Equipe de Recherche en Epidémiologie Nutritionnelle (EREN), Centre de Recherche en Epidémiologie et Biostatistiques, Inserm (U1153), Inra(U1125), Cnam, COMUE Sorbonne Paris Cité, F-93017 Bobigny, France.

74 rue Marcel Cachin F-93017 Bobigny Cedex. France.

+33 1 48 38 89 53

+33 1 48 38 89 31

Last name of authors: Julia, Péneau, Buscail, Gonzalez, Touvier, Hercberg, Kesse-Guyot

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Keywords: Front-of-pack nutrition labels; perception;

Abbreviations:
5-CNL: Five-colour nutrition label
FOP: Front-of-pack
FSA: Food Standards Agency
FSA-NPS DI : Food Standards Agency Nutrient Profiling System Dietary Index
NPS : Nutrient Profiling System
OfCom: Office of Communication
PNNS: Programme National Nutrition Santé
UK: United Kingdom

COPYRIGHT DECLARATION

ETHICS

The NutriNet-Santé study is conducted in accordance with the Declaration of Helsinki, and all procedures have been approved by the Institutional Review Board of the French Institute for Health and Medical Research (0000388FWA00005831) and the *Commission Nationale de l'Informatique et des Libertés* (908450 and 909216). Electronic informed consent was obtained from all participants. The Nutrinet-santé study is registered under EudraCT registration number 2013-000929-31.

TRANSPARENCY DECLARATION

Chantal Julia affirms that the manuscript is an honest, accurate, and transparent account of the study being reported; that no important aspects of the study have been omitted; and that any discrepancies from the study as planned (and, if relevant, registered) have been explained.

DATA SHARING

All necessary information is available in the paper.

ABSTRACT

Objective: Four formats for a front-of-pack (FOP) nutrition label are currently considered in France: the Nutriscore (or 5-Colour Nutrition Label, developed by a public research team), the SENS (supported by retailers), multiple traffic lights (MTL, currently used in UK) and a modified version of the Reference Intakes (mRIs, supported by industry). Our objective was to investigate the perception of these FOP labels, according to sociodemographic, lifestyle and dietary factors.

Design: Cross-sectional study

Setting: Web-based French cohort

Main outcome measure: FOP labels perception

Participants: Participants in the NutriNet-Santé cohort received a specific questionnaire on the perceptions of the four label formats identified. Socio-demographic, lifestyle and dietary data (three 24h dietary records) were collected through self-administered questionnaires. Mutually exclusive clusters of FOP labels perception were identified through a multiple correspondence analysis followed by a hierarchical clustering procedure. Socio-demographic, lifestyle and dietary factors associated with the clusters were explored using multivariable multinomial logistic regression. All analyses were weighted according to 2009 French census data.

Results: Among the 21,702 participants in the study, the Nutriscore received the most important number of favourable responses on positive perception dimensions by participants, followed by MTL and SENS. The 5 identified clusters were characterized by marked preferences for Nutriscore (Cluster 1, 43.2% of participants, crude N=9,399), MTL (Cluster 2, 27.3%, crude N=6,163), SENS (Cluster 3, 17.05%, crude N=3,546), mRIs (Cluster 4, 7.31%, crude N=1,632) and none of the presented formats (Cluster 5, 5.10%, crude N=965). The Cluster 1 (Nutriscore) was associated with lower adherence to nutritional recommendations, while Cluster 2 (MTL) was associated with younger age and higher level of education.

Conclusion: The Nutriscore appears to have a wide reach in the population and to appeal to subjects with lower adherence to nutritional recommendations.

ARTICLE SUMMARY

- Cross-sectional study in a large population using validated data collection tools.
- Investigation of multiple dimensions of the perception of FOP labels (awareness, liking, perceived cognitive workload and trustworthiness), across various formats that are currently proposed in the French debate on FOP nutrition labelling.
- Identification of clustered preferences towards each type of format, and investigation of the association between socio-demographic and dietary factors with FOP label preferences
- Sample consisting of volunteer subjects included in a cohort study on nutrition, who are therefore more likely health conscious.
- Focus on the perception of FOP labels, and not on understanding or use of FOP labels in purchasing situations.

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Study sponsors had no part in study design, collection, analysis, and interpretation of data and the writing of the article and the decision to submit it for publication. Researchers are independent from funders and sponsors. All researchers had access to all the data

CONFLICT OF INTEREST STATEMENT

All authors have completed the Unified Competing Interest form at www.icmje.org/coi_disclosure.pdf (available on request from the corresponding author) and declare that (1) No authors have support

from any company for the submitted work; (2) All authors have no relationships with any company that might have an interest in the submitted work in the previous 3 years; (3) their spouses, partners, or children have no financial relationships that may be relevant to the submitted work; and (4) All authors have no non-financial interests that may be relevant to the submitted work.

INTRODUCTION

Preventing non-communicable diseases has become a top priority for most industrialized countries, as they represent a major part of the burden of diseases (1). In France, cardiovascular diseases and cancers are the first causes of death, contributing each to approximately 30% of overall deaths every year (2). Diet has been recognized as a key modifiable factor which can influence – as preventive or risk factor – a wide range of non-communicable diseases, from cardiovascular disease to cancer, type 2 diabetes, metabolic syndrome or obesity (3-5). Given its potential lever for improvement of the health status of the population, most western countries have invested in state-level public health programs on nutrition, promoting healthy diets and physical activity (6-8). In France, the National Nutrition and Health Program (Programme National Nutrition et Santé, PNNS), launched in 2001 (9), sets a regulatory environment that promotes synergistic actions towards healthy eating and physical activity. The most pervasive actions that have been taken towards the population have consisted in the dissemination of nutrition recommendations in multimedia campaigns and booklets (10;11). Those recommendations act upon the nutrition knowledge of individuals, prompting them to modify their dietary behaviour by promoting consumption of some food groups (e.g. fruits and vegetables, whole-grain cereals, water) or limiting excessive intakes of others (saturated fat, added sugar and sodium) (12). Recently, novel complementary strategies have been put forward in a report to the French Minister of Health in 2014, highlighting the need for specific measures to modify the nutritional environment beyond the actions at the individual level (13). The report stressed in particular measures pertaining to nutrition labelling, in the form of a simplified front-of-pack (FOP) nutrition label, advertising regulation and nutritional taxation (13). Among the proposals of this report, the implementation of a FOP nutrition labelling system was considered as an effective opportunity by the Health Minister, and its principle was introduced in the 2016 French Health Law (14). Many countries have implemented FOP nutrition labels worldwide, either nutrient-specific, such as the 'Multiple Traffic Light' system in the UK (15) or summary measures, either simple – such as the Dutch 'Choices' logo (16) or the Nordic 'Green Keyhole' (17) – or graded – such as the 'Health Star Rating System' in New Zealand and Australia (18). Summary systems have been considered as more easily

understood and interpreted than nutrient-specific labels, in particular for vulnerable populations (19;20). Moreover, colour-coded systems are considered more favourably perceived than monochrome systems (20;21). The initial report to the French Health Minister contained a detailed proposal for a simple colour-coded and graded label, supported by scientific studies (22-34) and independent government agencies evaluations (35;36) in the form of the 5-Colour Nutrition Label (5-CNL). However, alternative proposals were put forward during the debate by industry and retailers, in a vast lobbying campaign (37). Finally, four alternative formats emerged in the debate: the Nutriscore (an updated graphical version of the 5-CNL), SENS (a summary, graded and colour-coded label, developed and promoted by retailers), Multiple Traffic Lights (MTL, nutrient-specific and colour-coded label, currently used in the United Kingdom, UK) and a modified version of the Reference Intakes (mRIs, a nutrient-specific and monochrome label promoted by industry) (**Figure 1**). However, to date, no scientific study has directly compared the perception of the four proposed formats. Some studies tend to indicate that the 5-CNL would be more favourably perceived than MTL or RIs (25)and that it may help consumers identifying (24;25) and purchasing healthier foods (26;34) but no data has been published on the mRIs or the SENS formats.

The objective of the present study was therefore to investigate the perception of the four formats that have been put forward in France in the debate on FOP nutrition labelling, in a comparative design carried out in the NutriNet-Santé cohort.

MATERIAL AND METHODS

Population

Participants were selected from the NutriNet-Santé cohort. Briefly, the NutriNet-santé study is a prospective cohort study set in France in which inclusion and follow-up of volunteer participants are entirely performed on the Internet (38). The main objectives of the NutriNet-santé study are: 1) to investigate the relationship between nutrition and health outcomes; and 2) to investigate the determinants of dietary patterns and nutritional status. Inclusion in the study began in May, 2009, and is still ongoing. Volunteer participants aged >18 years-old subscribe to the study, and are included

when they have completed a set of questionnaires assessing: diet (through repeated 24h dietary records), physical activity, anthropometry, lifestyle and socio-economic conditions and health status. These five types of questionnaires are repeated yearly and have been validated against traditional assessment methods (paper or interview by dieticians) (39-41). Once the subjects are included in the cohort, they receive monthly web-questionnaires pertaining to various aspects of dietary behaviour, physical activity and health, which are optional, and graded according to their relative importance for research. The participation rate for any optional questionnaires in the NutriNet-Santé study is usually around 40%. Participants do not receive any form of incentive or compensation to participate in the online surveys. One of these questionnaires pertained to the perception of the various FOP labelling systems that have been proposed in the French context and was sent to all participants in the cohort in June 2016.

Detailed information on the NutriNet-Santé study can be found elsewhere (38).

Ethics

The NutriNet-Santé study is conducted in accordance with the Declaration of Helsinki, and all procedures have been approved by the Institutional Review Board of the French Institute for Health and Medical Research (0000388FWA00005831) and the *Commission Nationale de l'Informatique et des Libertés* (908450 and 909216). Electronic informed consent was obtained from all participants. The NutriNet-Santé study is registered under EudraCT registration number 2013-000929-31.

Perception of FOP labels

A specific questionnaire was develop using survey items from previously published research to investigate participants' perceptions of the four FOP labelling formats that are currently being debated in France (25;42). The questionnaire also included other dimensions of FOP nutrition labelling evaluation (objective understanding and legitimacy), which were not used in this study. A brief presentation of the four FOP labels was provided for the participants at the beginning of the questionnaire on the perceptions of FOP labels. The presentation made no mention of the origin or

support by researchers or industry of each format, in order not to influence the participants based on this information.

Briefly, the Nutriscore, developed by the Nutritional Epidemiology Research Team (Equipe de Recherche en Epidémiologie Nutritionnelle, authors of this paper, EREN) scientific research team, and based on the British Food Standards Agency nutrient profiling system and adapted for the French context by the High Council for Public Health (36) presents for each food or beverage the overall nutritional quality on a 5-point colour-coded scale from Green to Red (**Figure 1**). SENS, supported by retailers, is based on a nutrient profiling system developed by a research team, and presents for each food or beverage a recommended frequency of consumption, with a 4 points colour-coded scale (Green, Blue, Orange and Purple) (**Figure 1**). MTL, implemented in Great Britain since 2005 presents the numeric values of the contribution of a portion of the food to the intakes in a balanced diet (in grams and percentage of reference intakes, corresponding to the reference intakes label) for energy, fats, saturated fats, sugar and sodium, with a colour-coding (Green, Amber and Red) for each of these components of the food (**Figure 1**). The Modified Reference Intakes (mRIs) present the numeric values of the reference intakes, in both grams and percentage of reference intakes, with bars varying in height depending on the amount of the component in the food (**Figure 1**).

Overall, 13 questions were asked on various aspects of liking (e.g. “This is my preferred FOP label”), trustworthiness (e.g. “This FOP label provides reliable information”), awareness (e.g. “This FOP label is easy to identify”) and perceived cognitive workload (e.g. “This label is too complex for understanding”) (**see Supplemental table 1**). For each question, subjects were asked to select among the four formats the label that best corresponded to them. The participants could also select that ‘none’ of the proposed labels corresponded to his/her perception.

Socio-demographic and lifestyle data

Socio-demographic and lifestyle data were collected through self-administered questionnaires and included age, sex, education (no diploma and up to secondary education, University ≤ 2 years, University > 2 years), marital status (in couple, single/divorced/widowed), income per household unit

(43) (<1200/month, 1200 – 1800, 1800 – 2700, ≥ 2700 €/month) and smoking status (current smoker, former smoker and never smoker). Physical activity was computed using self-declared data from the validated International Physical Activity Questionnaire (low, moderate and high physical activity levels) (44). The data collected in the questionnaire closest in time to the questionnaire on the perceptions of FOP labels were taken into account for the analyses.

Dietary data

Dietary data were derived from three repeated 24-hour records randomly distributed in a two-week period, with two week days and one week-end day. Food consumption was weighted according to the day of the week of each record. The participants are asked to estimate the portion size for each reported food and beverage item using validated photographs (45). Nutrient intake was computed using a published food composition database reflecting foods usually consumed in the French diet (46). Under- reporters for energy intake were identified using Goldberg/Black's method and were excluded (47). The dietary data from the 24h dietary record in the NutriNet-Sante study have been validated against interviewer-led dietary recalls conducted by trained dietitians, and against biomarkers of nutritional status (40;48;49).

Statistical analysis

For the present study, all participants who had completed the questionnaire on the perception of FOP labels, and having completed information on all covariates were eligible to the present study. Subjects were excluded if they stated that they never engaged in grocery shopping. The records and questionnaires closest to the questionnaire on the perceptions of FOP labels were taken into account for the analyses.

Weighting of the data

All data were weighted using the SAS CALMAR (CALage sur MARges) macro developed in France by the Institute of National Statistics (INSEE) to weight survey data to be representative of the French census population (50). Data used for weighting were sex, age and educational level.

Adherence to dietary recommendations

Adherence to French dietary recommendations was assessed using a modified version of the PNNS guidelines score (namely, the "*Programme National Nutrition Santé"*-guideline score, PNNS-GS), taking into account only dietary recommendations. The PNNS-GS development, including food groupings, serving sizes, scoring, cut-off and penalties, has been previously described in detail (51). Briefly, this 15-point score is based on French national guidelines and includes 13 components. The eight components referring to food serving recommendations and four components referring to moderation in consumption were included in the modified version of the PNNS-GS (mPNNS-GS) (52). The last component focusing on adherence to physical activity recommendations was not taken into account.

A penalty for overconsumption was assigned to individuals with energy intakes higher than estimated energy expenditure (51). Age and self-reported weight and height at inclusion were used to estimate Schofield's basal metabolic rate (BMR) (53). Energy expenditures were estimated using BMR and physical activity level. In case of energy intake greater than 5% over the estimated energy expenditure, an identical part was subtracted from the score. Quartiles of mPNNS-GS were computed and used throughout the analyses.

Dietary clusters identification

The responses from the 13 "perception" questions were used in a multiple correspondence analysis, which yielded 4 dimensions of FOP labelling perception. The dimensions were selected based on their adjusted inertia (respectively 33.6%, 23.0%, 18.4% and 17.2% for a total of 92.3%). The selected dimensions were used as input variables in a two-ways clustering procedure based on hierarchical and K-means methods (SAS CLUSTER and FASCLUST procedures). The plot of semi-partial R^2, the semi-partial T^2 and the Cubic Clustering Criterion (CCC) by the number of clusters were used to identify the optimal number of clusters.

Statistical analysis

All analyses were weighted according to the CALMAR macro, except the clustering procedure for which no weighting option is available. The responses to each of the 13 questions were mapped across clusters, in order to identify the FOP perception characteristics of each cluster. Socio-demographic, lifestyle and dietary variables were mutually adjusted against clusters in a multivariable multinomial regression. Adjusted-percentages for each socio-demographic, lifestyle and dietary characteristic were extracted from this procedure across clusters.

All tests were two-sided and a P value <0.01 was considered significant, given the high number of statistical tests performed and the large sample size. Statistical analyses were performed using SAS Software (version 9.3, SAS Institute Inc, Cary, NC, USA).

RESULTS

Overall, 38,604 subjects completed the questionnaire on the perceptions of FOP labels. Among these, 714 (1.85%) were excluded because they never engaged in grocery shopping. Among the 37,890 remaining subjects, 16,188 (42.72%) were excluded for incomplete data on covariates (the vast majority of which (N=13,066, 80.71% of excluded subjects) for incomplete data on mPNNS-GS computation, which requires the presence of three 24h records, frequency questionnaire on alcohol consumption and frequency of seafood consumption, leading to an overall sample of 21,702 participants for analysis (e.g. 56.22%).

Characteristics of the crude and weighted sample are presented in **Table 1**. The crude sample exhibited a higher percentage of females (73.42%), older subjects (68.36% were ≥ 50 years-old), educated (37.54% had above 2 years of university training) and with high incomes (38.49% had incomes >2700€/month).

Overall, the Nutriscore was the label receiving the most important number of favourable responses on positive perception dimensions by participants, followed by MTL and SENS (43.79% of participants considered the Nutriscore as their preferred FOP label, followed by 24.92% for MTL and 17.17% for SENS) (**Table 2**). Conversely, RIs yielded the highest number of responses on negative dimensions of

perception (complexity and time processing). A majority of participants considered that none of the proposed labels were guilt-laden (50.23%), followed by SENS (21.19%)

The clustering procedure resulted in the identification of 5 mutually exclusive groups of subjects according to their perception of FOP nutrition labels. Clusters represented 43.23% (crude N=9,399), 27.31% (crude N=6,163), 17.05% (crude N=3,546), 7.31% (crude N=1,632) and 5.10% (crude N=965) of participants, respectively. The mapping of perception responses across clusters showed that each cluster was characterized by a marked preference for one of the proposed FOP nutrition label formats: Cluster 1 displayed a marked preference for the Nutriscore, Cluster 2 for the MTL, Cluster 3 for the SENS, Cluster 4 for the RIs and Cluster 5 for none of the presented labels (**Figure 2; see Supplemental Table 2 for detail**). Therefore, clusters were termed according to their label preference. These preferences across cluster were particularly prominent for the following aspects: label wanted on the front of the packages (>85% for each specific FOP label in their respective cluster), preferred label (>80% for each specific label in their respective cluster), label allowing to choose healthier products (>65% for each specific label in their respective cluster), trustworthiness (>74% for each specific label in their respective cluster) (**Figure 2; see Supplemental Table 2 for detail**). However, for some dimensions of perception, responses were somewhat less marked for each specific FOP label, and more concurrent across clusters. For example, >23% of participants in all clusters considered that the Nutriscore was quick to process, >19% considered it easy to identify, and >17% considered it easy to understand (**Figure 2; see Supplemental Table 2 for detail**). Conversely, >20% of participants in all clusters considered the mRIs to be too complex for understanding (except in its own where it obtained 10.90% of opinions), >19% considered it too long to understand (except in its own cluster, with 12.73% of opinions), and was considered as the least appreciated FOP nutrition label for 66.88% of subjects in the Cluster Nutriscore, 61.86% of subjects in the Cluster SENS, 39.88% of subjects in the Cluster MTL and 10.78% of subjects in the Cluster None (**Figure 2; see Supplemental Table 2 for detail**). Finally, participants considered that none of the presented labels was guilt-laden: 87.12% of Cluster None, 49.93% of Cluster Nutriscore, 47.89% of Cluster MTL,

47.80% of Cluster mRIs and 44.78% of Cluster SENS (**Figure 2; see Supplemental Table 2 for detail**).

Multivariable adjusted socio-demographic characteristics according to specific clusters are shown in **Table 3**. Less educated subjects were more frequent in Cluster None and Cluster mRIs and highly educated subjects in Cluster MTL (**Table 2**). Smokers were more likely in Cluster None, while never smokers were more likely in Cluster Nutriscore. Subjects with low physical activity were more likely in Cluster SENS and Cluster Nutriscore (**Table 2**). Finally, subjects with lower adherence to dietary recommendations (Quartile 1 of mPNNS-GS) were more likely in Cluster None and Cluster Nutriscore while subjects with high adherence to dietary recommendations (Quartile 4 of mPNNS-GS) were more likely in Cluster mRIs and Cluster MTL (**Table 2**).

DISCUSSION

Our study showed that the perception of FOP labels can be clustered according to consistent preferences for specific formats. Among the proposed labels in the current French debate, the Nutriscore appeared to be the most preferred format, followed by MTL. Moreover, though each cluster presented marked preferences for one type of format or another, the Nutriscore appeared to reach to participants beyond its specific cluster, as it was considered easy to identify and understand by a significant number of participants in other clusters. Finally, socio-demographic characteristics appeared to be associated with each cluster, with a specific cluster (Cluster 5, None), concentrating high percentages of subjects presenting disadvantaged socio-demographic characteristics (lower levels of education) and lifestyle risks (smoking, low level of physical activity and low adherence to dietary recommendations).

Compared to a previous study conducted in early 2015 using a similar methodology and among participants in the same cohort study, the results of the present analyses show that the reach of the Nutriscore has somewhat broadened since then (25). The Nutriscore appeared to have a wide reach in the population, and to appeal to subjects with lower adherence to dietary recommendations. This result shows that the Nutriscore may be an effective complementary strategy to current public health

nutrition policies, which promote healthy eating through widely disseminated nutritional recommendations (54). Though this strategy has led to an increase in the knowledge of nutritional recommendations, consumers somehow struggle to translate such advice into action (55;56). Disseminated nutrition information is suggested to appeal more to those already having the capacity to implement nutritional knowledge (through higher education or income), and may lead to an increase in social disparities in health (57;58). Therefore, the fact that the Nutriscore appears to appeal to subjects with low adherence to nutrition recommendations may be a key element to help translating nutritional recommendations into practice, in particular for those with low nutritional knowledge.

The MTL appeared as the second preferred FOP label in the population, particularly in younger subjects, with university education and lower incomes. Moreover it was considered to be providing reliable and useful information beyond its own cluster. The fact that direct numeric information on nutrient content (such as the information provided by mRIs) received a much lower support in the population shows that the appeal of the MTL is very probably associated with the colour feature of this FOP label (59), as multiple numeric information are typically considered difficult to understand (60). Indeed, compared to mRIs, the MTL only adds an interpretation of the level of nutrients using a colour-coding. However, the interpretation of the colour-coding has appeared to be challenging in certain populations (59). Indeed, MTL is a nutrient-specific FOP label, giving individual information for energy and four nutrients (sugars, fat, saturated fat and salt). Multiple nutrient-related information implies first that consumers are able to identify the nutrients that are referred to, and second, that they are able to prioritize the information provided for each nutrient (42;61). Indeed, MTL can lead to conflicting choice options: for example, the comparison between two products, with the same number of nutrients coded in ‘red’, but not for the same nutrients (e.g. one with a ‘red’ code for sugar and the other for saturated fatty acids) implies for the consumer to be able to single out one of the nutrients in order to make a choice (21). These characteristics of the label may in part explain the fact that the MTL appeared to appeal more particularly to young, educated subjects with a high level of adherence to nutritional recommendations. This more favourable perception among these participants may stem from their higher nutritional knowledge, which allows them to better interpret the label and act upon it

in purchasing situations (21;60). However, this specific reach in terms of population might also lead to widen inequalities in health and nutrition if implemented in the overall population (62).

The SENS system was the preferred system for 17% of the population, more particularly in households with children. The graphical system the SENS originated from was developed by a marketing team from a retailer in September 2014, and received later support from the French retailers' federation (37). As for Nutriscore or MTL, it is based on colour coding (though not based on the polychromatic Green-Red scale), with the addition of recommended frequencies of consumption for each level of the label. This latter feature may in part explain the higher appeal of the SENS system on participants with children, as it gives a more specific guidance for consumption, which can be used for children. However, these specific consumption frequencies for each level of the label could also be interpreted as an oversimplification and a form of paternalism for many consumers (63). This may be one of the reasons the SENS label was considered as a guilt-laden label for 21.2% of the population.

Moreover, though Nutriscore and MTL rely on the well-known polychromatic scale from green to red (corresponding to recognized signals), which are easier to interpret, the SENS colour-coding does not refer directly to any known colour scale (its levels are Green-Blue-Orange-Purple). Colours are considered helpful to generally increase the salience of a FOP label, however, studies that have shown a specific advantage of colour-coding have used readily interpretative colour-coding (63-66). In the study by Bialkova et al., which used polychromatic RIs, but with no readily-interpretative colours (yellow, orange, purple, blue), the polychromatic RIs indeed had lower performance than monochromatic RIs (64). Therefore, beyond preference only, the use of highly interpretable colours (e.g. 'Green' and 'Red') in a FOP labelling system might be an important feature of a colour coding.

Finally, our study shows that a portion of the population appeared to disregard or even reject FOP nutrition labels entirely. Indeed, participants in Cluster 5 (None, corresponding to 5.1% of the population) consistently responded 'None' for all dimensions of perception that were investigated. Moreover, the socio-demographic characteristics of this specific population suggested that they may in fact be more vulnerable and more at nutritional risk than the rest of the population. Indeed, this cluster

included more specifically older participants, subjects with lower educational levels, current smokers and subjects with lower adherence to nutritional recommendations. This result is in line with a study in Australia showing that males and subjects with lower socio-economic status were more likely to report no preference for a FOP label (67). These results also pose a challenge to the design of efficient public health policies, as some of the subjects who would certainly benefit from them appear to reject them. Novel and targeted interventions in public health nutrition should therefore be devised to appeal to this vulnerable population to entice them towards healthier diets, taking into account the broader environment related to risk behaviours (68). Alternatively, policies targeting the environment, and not depending on individual choices, such as the reformulation of existing products, may have an indirect impact on these populations (69).

Strengths of our study include its large sample size for an online survey, based on an ongoing dynamic cohort study performed exclusively online. Moreover, the data used for the investigation of dietary intakes used validated data collection tools, using repeated dietary records (40). We were also able to investigate multiple dimensions of the perception of FOP labels (awareness, liking, perceived cognitive workload and trustworthiness), across various formats that are currently proposed in the French debate on FOP nutrition labelling. Finally, we were able to identify clustered preferences towards each type of format, and relate them to socio-demographic and dietary factors, which highly contributed to the interpretation of such preferences in a public health perspective.

Our study is subject to some limitations. First, our sample consists of volunteer subjects included in a cohort study on nutrition, who are therefore more likely health conscious. The completion of the questionnaire was optional, and the participation rate was therefore not optimal, which could have also added to a selection bias in our study population. However, our data shows a wide variety of dietary profiles, somewhat lessening the importance of this bias. Moreover, the use of weighting partially controlled for the selection bias of our study population (70). Second, our study focused on the perception of FOP labels, and not on understanding or use of FOP labels in purchasing situations. However, following the theoretical framework for the use of FOP nutrition labels, favourable perception is a crucial pre-requisite for the efficiency of a given label (71;72). Third, the participants

in the NutriNet-Santé study had already been involved in a previous survey on the perception of various FOP nutrition labels (25). However, the formats presented in the two versions of the questionnaire were somewhat different, and the delay between the two questionnaires of more than a year, therefore limiting the familiarity of the participants with the FOP nutrition labels formats displayed in this study. However, the participants were aware of FOP nutrition labelling, which could have affected their responses. Finally, the questionnaire for the online survey and the measures that were used in this study were not formally validated but based on scientific literature. They derived from previously published work which took into account the literature on the perception of FOP nutrition labelling (42;61;73).

To conclude, FOP nutrition labels could be useful strategies to tackle social inequalities in nutrition and health, provided that the graphical format that is selected has a wide reach in the population. This is all the more important that subjects who are more concerned about their diet (and more likely to have a healthier diet), are also more likely to use a nutrition label when grocery shopping (20). As such, the Nutriscore, which has a favourable perception among subjects with low adherence to nutritional recommendations, may be a helpful strategy to lead them towards healthier diets.

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AUTHORSHIP CONTRIBUTION

CJ wrote the statistical analysis plan, analysed the data, and drafted and revised the paper. She is the guarantor. EKG participated in statistical analysis plan, analysed the data and critically revised the paper for important intellectual content. MT CB SP RG analysed the data and critically revised the paper for important intellectual content. SH designed data collection tools, implemented the study, monitored data collection for the whole study, and critically revised the draft paper for important intellectual content. All authors, external and internal, had full access to all of the data (including statistical reports and tables) in the study and can take responsibility for the integrity of the data and the accuracy of the data analysis. All authors have read and approved the final manuscript.

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FIGURE LEGENDS

Figure 1: Formats proposed for a front-of-pack nutrition label in France.

Caption:

Nutriscore developed by the EREN research team, is based on the British Food Standards Agency nutrient profiling system and presents for each food or beverage the overall nutritional quality on a five-point colour-code scale from Green to Red.

SENS, supported by retailers, is based on a nutrient profiling system developed by a research team, and presents for each food or beverage a recommended frequency of consumption, with a four points colour-coded scale (Green, Blue, Orange, Purple)

Multiple Traffic Lights, supported by industry, and implemented in Great Britain since 2005 presents the numeric values of the contribution of a portion of the food to the intakes in a balanced diet (in grams and percentage of reference intakes, corresponding to the reference intakes label, RI) for energy, fats, saturated fats, sugar and sodium, with a colour-coding (Green, Amber and Red) for each of these components of the food

Modified Reference Intakes (mRIs) present the numeric values of the reference intakes, in both grams and percentage of reference intakes, with bars varying in height depending on the amount of the component in the food.

Figure 2: Responses to each of the dimensions of perception in the various clusters

Caption: Each circle represents a cluster, each response to a dimension is scaled within the cluster. Positive dimensions are situated on the right hand side of the figure, while negative dimensions are situated on the left hand side of the figure

Table 1 Characteristics of the study population, crude and after weighting

		Crude		Weighted
		n	%	%
Sex				
	Men	5768	26.58	39.97
	Women	15934	73.42	60.03
Age				
	18-29 years-old	968	4.46	12.28
	30-49 years-old	5900	27.19	31.05
	50-64 years-old	7899	36.40	29.39
	≥ 65 years old	6935	31.96	27.28
Educational level				
	Up to secondary	6804	31.35	70.54
	University, up to two years	6750	31.10	13.86
	University, ≥ 3 years	8148	37.54	15.60
Income per consumption unit				
	<1200/month	2068	9.53	20.28
	[1200 - 1800[€/month	4766	21.96	30.24
	[1800 - 2700[€/month	6514	30.02	28.67
	≥ 2700 €/month	8354	38.49	20.81
Household composition				
	Adults only	17118	78.88	78.05
	Adults and children	4584	21.12	21.95
Smoking status				
	Current smoker	1923	8.86	10.16
	Former smoker	8710	40.13	39.81
	Never smoker	11069	51.00	50.03
Physical activity level				
	High	8007	36.90	39.01
	Moderate	9128	42.06	37.28
	Low	4567	21.04	23.72
mPNNS-GS				
	Quartile 1	5425	25.00	23.70
	Quartile 2	5582	25.72	23.86
	Quartile 3	5933	27.34	26.20
	Quartile 4	4762	21.94	26.24

Weighting was obtained using the SAS CALMAR Macro

Table 2 Crude percentage of responses to the dimensions of perception of FOP labels

	Nutriscore	MTL	SENS	mRIs	None
This FOP label is helpful to choose healthier products	40.02	26.93	17.33	9.14	6.57
I want to see this FOP label on the front of packages	44.22	25.15	17.15	7.43	6.05
This is my preferred FOP label	43.79	24.92	17.17	6.68	7.45
This FOP label provides me with the information I need	24.51	43.06	15.78	11.44	5.21
This FOP label is trustworthy	37.64	28.83	15.23	8.52	9.79
This FOP label provides reliable information	26.76	40.32	10.55	11.75	10.62
This FOP label is easy to identify	62.53	8.78	21.37	2.75	4.56
This label is easy to understand	52.22	7.86	33.5	3.43	2.99
This FOP label is quick to process	64.09	8.07	22.27	2.9	2.68
This FOP label is too complex for understanding	4.49	19.9	5.7	48.22	21.7
This FOP label takes too long to understand	2.52	25.45	2.86	50.81	18.36
This is the FOP label I appreciate the least	9.67	12.58	17.44	51.33	8.98
This FOP label is guilt-laden	12.42	9.32	21.19	6.83	50.23

Table 3 Multivariable adjusted socio-demographic, lifestyle and dietary characteristics according to the various clusters of preference for FOP nutrition labeling

		Nutriscore	MTL	SENS	mRIs	None	*P*
		43.23	27.31	17.05	7.31	5.10	
Sex							*<0,0001*
	Men	**41.88**	37.23	37.48	**35.67**	40.14	
	Women	58.12	62.77	62.52	64.33	59.86	
Age							*<0,0001*
	18-29 years-old	11.11	**13.90**	11.06	11.82	3.93	
	30-49 years-old	64.66	68.43	67.53	66.86	64.92	
	50-64 years-old	21.40	15.86	19.04	18.05	25.76	
	≥ 65 years old	2.84	1.81	2.37	3.27	**5.40**	
Educational level							*<0,0001*
	Up to secondary	72.64	67.59	72.05	77.71	**77.84**	
	University, up to two years	15.26	16.81	15.72	12.79	12.21	
	University, ≥ 3 years	12.09	**15.61**	12.23	9.50	9.95	
Income per consumption unit							*<0,0001*
	<1200/month	14.57	**20.07**	16.36	17.17	13.95	
	[1200 - 1800[€/month	32.61	31.47	35.57	35.71	36.83	
	[1800 - 2700[€/month	30.96	29.29	29.41	29.17	30.45	
	≥ 2700 €/month	**21.85**	19.16	18.66	17.96	18.77	
Household composition							*<0,0001*
	Adults only	87.76	88.57	86.99	88.60	**90.35**	
	Adults and children	12.24	11.43	**13.01**	11.40	9.65	
Smoking status							*<0,0001*
	Current smoker	10.91	11.33	9.94	9.35	**15.59**	
	Former smoker	31.74	34.95	34.21	35.63	32.69	
	Never smoker	**57.35**	53.72	55.85	55.02	51.73	
Physical activity level							*<0,0001*
	High	31.73	34.19	31.12	**35.93**	29.38	
	Moderate	40.97	44.91	41.20	41.62	43.90	
	Low	27.30	20.90	**27.68**	22.44	26.71	
mPNNS-GS							*<0,0001*
	Quartile 1	28.28	25.09	23.90	21.63	**32.47**	
	Quartile 2	25.90	22.09	26.67	20.08	30.08	
	Quartile 3	26.86	28.44	26.96	30.87	21.86	
	Quartile 4	18.96	24.37	22.47	27.42	**15.59**	

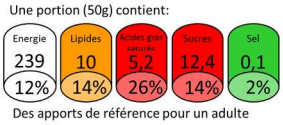
Mutually adjusted percentages obtained with multinomial regression

Nutriscore

SENS

Modified Reference Intakes

Multiple Traffic Lights



Formats proposed for a front-of-pack nutrition label in France.
Caption:
Nutriscore developed by the EREN research team, is based on the British Food Standards Agency nutrient profiling system and presents for each food or beverage the overall nutritional quality on a five-point colour-code scale from Green to Red.
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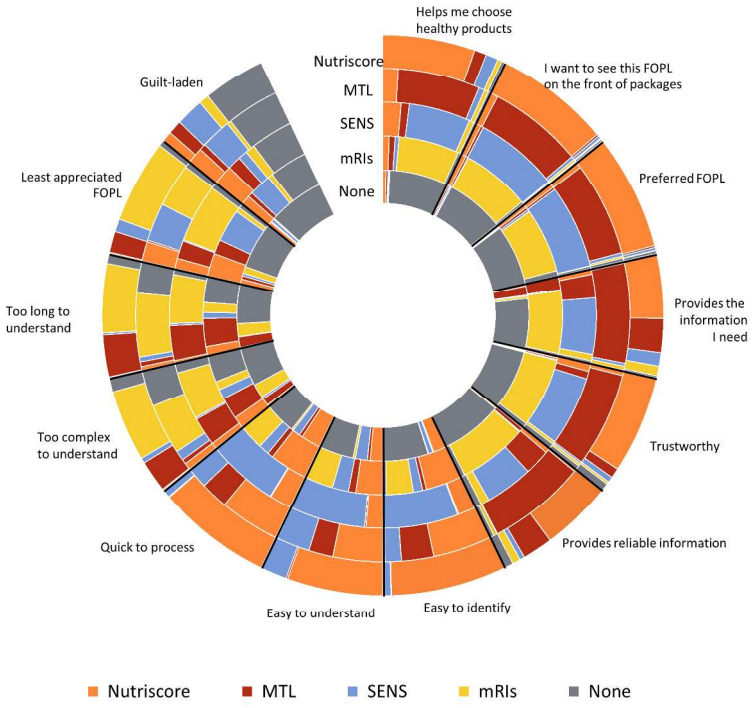
Modified Reference Intakes (mRIs) present the numeric values of the reference intakes, in both grams and percentage of reference intakes, with bars varying in height depending on the amount of the component in the food.

254x190mm (300 x 300 DPI)



Responses to each of the dimensions of perception in the various clusters
Caption: Each circle represents a cluster, each response to a dimension is scaled within the cluster. Positive dimensions are situated on the right hand side of the figure, while negative dimensions are situated on the left hand side of the figure

254x190mm (300 x 300 DPI)

Online supplementary material

Supplemental Table 1 Questionnaire used to assess perception of the various FOP nutrition labels (French version and English translation)

Question (English Translation)	Question (Original question in French)
This FOP label is helpful to choose healthier products	Ce logo aide à choisir des produits meilleurs pour la santé
I want to see this FOP label on the front of packages	Je veux qu'il soit présent sur les emballages
This is my preferred FOP label	C'est mon logo préféré
This is the FOP label I appreciate the least	C'est le logo que j'aime le moins
This FOP label provides me with the information I need	Ce logo m'apporte l'information dont j'ai besoin
This FOP label is trustworthy	Ce logo m'inspire confiance
This FOP label provides reliable information	Ce logo permet d'avoir une information fiable
This FOP label is easy to identify	Ce logo est facile à repérer
This label is easy to understand	Ce logo est facile à comprendre
This FOP label is quick to process	Ce logo permet d'avoir une information rapide
This FOP label is too complex for understanding	Ce logo est trop compliqué à comprendre
This FOP label takes too long to understand	Ce logo est trop long à comprendre
This FOP label is guilt-laden	Ce logo est culpabilisant

Online supplementary material

Supplemental Table 2 responses to perception questions according clusters of preference for FOP nutrition labeling

Liking

	Nutriscore	MTL	SENS	mRIs	None
This FOP label is helpful to choose healthier products					
Nutriscore	74.32	13.93	19.21	7.81	4.84
SENS	9.91	5.45	65.23	4.96	1.54
MTL	9.78	75.12	8.65	7.54	3.2
mRIs	3.64	3.86	5.23	76.19	1.03
None	2.36	1.64	1.68	3.51	89.4
I want to see this FOP label on the front of packages					
Nutriscore	93.45	7.64	6.32	6.89	3.1
SENS	2.34	2.99	88.89	0.66	2.35
MTL	1.73	86.27	2.92	2.75	2.73
mRIs	0.82	2.21	0.59	86.66	0.81
None	1.66	0.89	1.28	3.04	91
This is my preferred FOP label					
Nutriscore	93.51	6.24	6.18	5.94	3.33
SENS	2.3	3.12	88.31	2.9	1.05
MTL	1.53	86.06	2.54	3.23	1.7
mRIs	0.33	1.84	0.42	81.23	0.47
None	2.33	2.74	2.55	6.7	93.45
This is the FOP label I appreciate the least					
Nutriscore	1.08	17.92	10.9	28.78	6.79
SENS	10.36	34.9	1.31	41.12	3.96
MTL	16.91	1.51	19.14	18.16	5.23
mRIs	66.88	39.88	61.86	5.85	10.78
None	4.77	5.78	6.78	6.09	73.24

Online supplementary material

Awareness and trustworthiness

	Nutriscore	MTL	SENS	mRIs	None
This FOP label provides me with the information I need					
Nutriscore	52.36	2.01	6.25	0.56	4.21
SENS	10.83	2.66	59.59	1.74	1.71
MTL	27.37	91.49	25.14	16.79	14.24
mRIs	7.78	3.58	6.87	78.6	3.66
None	1.67	0.25	2.16	2.31	76.17
This FOP label is trustworthy					
Nutriscore	79.33	4.82	9.29	3.48	3.67
SENS	4.55	1.79	74.04	0.98	1.5
MTL	7.98	87.15	8.04	1.98	1.21
mRIs	1.96	2.43	3.35	87.89	0.28
None	6.18	3.81	5.29	5.67	93.34
This FOP label provides reliable information					
Nutriscore	57.78	2.37	5.76	1.95	0.23
SENS	3.92	0.48	50.74	0.88	0.12
MTL	24.47	90.22	27.44	4.67	1.53
mRIs	6.54	3.18	9.22	87.05	2.36
None	7.29	3.75	6.84	5.45	95.75
This FOP label is easy to identify					
Nutriscore	93.08	53.69	19.15	45.28	20.69
SENS	6.03	15.02	79.02	11.56	6.82
MTL	0.34	29.44	0.99	4.83	1.41
mRIs	0.08	0.6	0.32	33.66	0.78
None	0.47	1.25	0.53	4.68	70.29

Online supplementary material

Perceived cognitive workload

	Nutriscore	MTL	SENS	mRIs	None
This label is easy to understand					
Nutriscore	77.11	45.5	17.55	33.92	19.4
SENS	20.75	30.45	80.77	20.47	18.54
MTL	1.41	22.27	1.58	9.16	4.46
mRIs	0.51	1.46	0.09	35.6	3.72
None	0.22	0.33	0	0.85	53.88
This FOP label is quick to process					
Nutriscore	92.72	55.07	23.2	47.31	30.42
SENS	6.18	18.75	75.65	13.43	11.67
MTL	0.62	25.17	0.75	7.31	5.22
mRIs	0.38	0.88	0.39	31.18	2.88
None	0.1	0.12	0.01	0.78	49.82
This FOP label is too complex for understanding					
Nutriscore	0.99	6.38	6.36	14.98	2.75
SENS	4.23	9.09	1.86	12.2	3.51
MTL	25.49	4.24	30.07	27.56	11.35
mRIs	57.73	46.53	50.78	10.9	21.55
None	11.56	33.77	10.92	34.35	60.84
This FOP label takes too long to understand					
Nutriscore	0.77	3.45	2.37	11.12	0.65
SENS	1.57	4.47	2.19	7.43	0.81
MTL	33.71	4.33	36.95	35.12	16.19
mRIs	55.76	58.12	52.13	12.73	19.83
None	8.19	29.63	6.36	33.6	62.51
This FOP label is guilt-laden					
Nutriscore	8.33	14.8	21.33	12.13	4.97
SENS	22.37	27.72	9.68	28.3	4.59
MTL	11.15	5.87	14.04	5.84	1.59
mRIs	8.23	3.73	10.16	5.93	1.73
None	49.93	47.89	44.78	47.8	87.12

Online supplementary material

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract **Page 4**
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found **Page 4**
Introduction		
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported **Page 6**
Objectives	3	State specific objectives, including any prespecified hypotheses **Page 7**
Methods		
Study design	4	Present key elements of study design early in the paper **Page 8**
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection **Page 8**
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants **Page 8-10**
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable **Page 8-10**
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group **Page 8-10**
Bias	9	Describe any efforts to address potential sources of bias **Page 10**
Study size	10	Explain how the study size was arrived at **Page 11**
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why **Page 8-10**
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding **Page 10-11**
		(*b*) Describe any methods used to examine subgroups and interactions **Not applicable**
		(*c*) Explain how missing data were addressed **Page 10**
		(*d*) If applicable, describe analytical methods taking account of sampling strategy **Not Applicable**
		(*e*) Describe any sensitivity analyses **Not Applicable**
Results		
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed **Page 11**
		(b) Give reasons for non-participation at each stage **Page 11**
		(c) Consider use of a flow diagram
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders **Page 12, Table 1**
		(b) Indicate number of participants with missing data for each variable of interest **Page 11**
Outcome data	15*	Report numbers of outcome events or summary measures **Page 12, Table 2**
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were

		adjusted for and why they were included **Page 12-13, Tables**
		(*b*) Report category boundaries when continuous variables were categorized **Page 8-10, Tables**
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period **Not Applicable**
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses
Discussion		
Key results	18	Summarise key results with reference to study objectives **Page 13**
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias **Page 16**
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence **Page 13-16**
Generalisability	21	Discuss the generalisability (external validity) of the study results **Page 16**
Other information		
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based **Page 3**

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.