Title: Leveraging artificial intelligence to monitor unhealthy food/brand marketing to children on digital media

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Keywords: Artificial intelligence; Machine learning; Unhealthy food/brand marketing; Children; Digital media; Dietary intake; Child health; Nutrition policy

Food/brand marketing refers to commercial promotions designed to increase recognition, appeal and/or consumption of particular foods and brands.[1] Successive systematic reviews have confirmed that unhealthy food/brand marketing, particularly on television and within advergames, adversely affects children's diet quality and diet-related health (e.g.[2,3]).

Whereas marketing has traditionally entailed one-way communication of a limited amount of information in a particular time and place (e.g. television commercials), digital media, including overt and covert (e.g. product placement, social media influencers) promotional activities on websites, social media, text, applications, email and online games, allow marketers to push unprecedented volumes of information to children in real-time, often using artificial intelligence (AI)-enabled tactics.[4,5] In the digital age, commercial messages no longer interrupt, but are instead intimately integrated with content,[6] and thus cues that can help children identify marketing (e.g. commercial breaks) are absent or not prominently displayed.[7] As such, children have much more difficulty recognizing marketing on websites compared to on television, making it difficult for them to initiate consumer defenses.[7] Digital marketing may therefore foster deeper and more sustained engagement with unhealthy foods/brands, with potentially more negative dietary and health consequences.[4]

However, while industry has leveraged AI to market unhealthy foods/brands to children on digital media, researchers continue to manually assess the extent and nature of these AI-enabled tactics. As such, even the largest international studies have only examined unhealthy food/brand marketing on a few hundred websites or gaming applications, or small numbers of social media accounts or YouTube channels (see examples in the Appendix). Given the massive size, dynamic and varied nature of digital marketing, manual approaches clearly lack appropriate speed, cost-effectiveness, feasibility, and scalability. This failure to leverage AI precludes more comprehensive understanding of the extent and nature of digital marketing of unhealthy foods/brands to children and hinders development of effective policy responses to protect children from this marketing.

In 2010, the World Health Assembly recommended that all Member States restrict unhealthy food/brand marketing to children across all media.[8] At least 16 countries have now imposed statutory restrictions on food/brand marketing to children, however few regulate marketing on digital media.[9] Widespread reluctance to regulate digital media has been attributed to evidentiary gaps concerning the extent and nature of the digital marketing problem, and the difficulty of monitoring policy adherence.[7,10] Such concerns are justified, as policy makers require evidence to justify regulatory intervention and inform policy provisions (e.g. what constitutes marketing to children), and a robust means to monitor adherence.

Importantly, AI can address these and many other challenges related to digital food/brand marketing that currently confront researchers and policymakers. AI makes it possible to automate tasks that require substantial human effort, or that cannot be accomplished at all by humans. Tasks can range from simple computational tasks (e.g. retrieve nutrition information for a food) to those that are highly complex (e.g. identify child-targeted marketing). Given the volume (e.g. millions of websites), velocity (e.g. content changes frequently) and variety (e.g. games, contests, display ads) of digital marketing, AI is essential for research and policymaking in the digital sphere. Most successful AI systems use machine learning, in which machines learn how to perform tasks by automatically identifying and learning from patterns in the data, rather than by being programmed to follow a specific routine. The application of AI can allow researchers to efficiently and accurately automate processes of extracting features (e.g. foods, brands, marketing strategies) from text, images and videos; mapping marketed foods/brands to

nutrition information; identifying child-targeting; classifying marketing strategies; and others. Such an AI system can be used to comprehensively (e.g. across millions of websites) and frequently (e.g. daily) assess the extent and nature of digital food/brand marketing to children and adherence to policy, including compensatory changes in unregulated forms of marketing that may result (e.g. advertisers may target adolescents more often if marketing to children is restricted).

The WHO's CLICK monitoring framework helpfully elaborates how a combination of methods including manual content analyses, novel software and apps can facilitate monitoring of food/brand marketing to children on digital media (http://www.euro.who.int/en/health-topics/disease-prevention/nutrition/publications/2019/monitoring-and-restricting-digital-marketing-of-unhealthy-products-to-children-and-adolescents-2019). A particular strength of the framework is its attempt to characterize targeted and personalized marketing to children, albeit primarily through more conventional approaches that catalogue what representative panels of children view in digital environments. Crucially, however, the CLICK framework does not encompass AI. This omission is important, as AI is currently the only feasible means of coping with the massive volume, variety and dynamic nature of digital food/brand marketing. If we are to succeed in curtailing unhealthy food/brand marketing to children, the power of AI must be leveraged for research and monitoring purposes. AI can complement CLICK by providing a more comprehensive perspective of the frequency and nature of unhealthy food/brand marketing to children on digital media, and by enabling rapid detection of policy breaches that CLICK either cannot, or may take substantially longer to uncover. We therefore propose the following seven-step process for developing an AI system to monitor unhealthy food/brand marketing to children on digital media (Figure 1).

1) Collect marketing instances on children's most frequently used digital media. A starting point could be websites, mobile gaming apps and YouTube videos with high numbers of child users, as determined via commercial marketing data.
2) Extract marketing features from each marketing instance collected in Step 1. In most instances, existing application programming interfaces (APIs) can be used for this purpose (e.g. Google Vision API (https://cloud.google.com/vision/)).
3) Determine whether marketing features extracted in Step 2 relate to foods/brands. This step can entail supervised learning techniques that have proven successful in health applications, including support vector machines, random forests, XGBoost (https://github.com/dmlc/xgboost), and deep learning.
4) Extract nutrition information from each food/brand marketing instance (e.g. using Spoonacular API (https://spoonacular.com/about). Develop an algorithm to evaluate the healthfulness of foods/brands using nutrient profiling systems specified in policy.
5) Develop machine learning models to classify the types of marketing strategies featured in each food/brand marketing instance (e.g. child-targeted or not).
6) Develop a rules-based algorithm to integrate results from Steps 4 and 5 to determine whether each food/brand marketing instance adheres to policy.
7) Aggregate and visualize decisions on individual food/brand marketing instances on a visual dashboard.

Together with the WHO's CLICK monitoring framework, AI methodologies can enable a comprehensive perspective of the digital food/brand marketing landscape that will inform policy

development. Moreover, when used in tandem, CLICK and AI can provide a robust basis to monitor compliance with policy and encourage industry adherence, thereby helping to ensure children receive maximum protection. In this way, AI is essential to enable children to participate in the digital world without negatively impacting their long-term health.

Declaration of interests: Dr. Olstad and Dr. Lee report grants from the Canadian Institutes of Health Research and the New Frontiers in Research Fund during the conduct of the study. In addition, Dr. Olstad and Dr. Lee have a planned patent.

Acknowledgments: This research was funded by the Canadian Institutes of Health Research (FRN 165925; FRN 166212) and the New Frontiers in Research Fund (NFRFE-2018-00793). The funders had no role in writing the manuscript or in the decision to submit it for publication. The authors were not paid to write this article by a pharmaceutical company or other agency. DLO had full access to all the data in the study and had final responsibility for the decision to submit it for publication.

Author contributions: DLO and JL co-wrote the manuscript.

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