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Assessing the visual aspect of rotating virtual rose bushes by a labeled sorting task

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ABSTRACT

Aesthetics is one of the major parameters for consumers when buying a rose bush. Therefore, managing this quality is important for agronomists. Tools are needed to assess visual characteristics and to find links with architectural plant parameters. Sensory analyses were developed using real plants and photographs as stimuli. With technology and modeling improvements, using virtual plants could presents numerous advantages. This study demonstrated the feasibility of using rotating virtual rose bush videos as stimuli for a labeled sorting task. The virtual rose bush reflected a natural within-crop variability of one cultivar based on bud breaks location and axes length. Two panels of subjects closely linked to the horticulture sector sorted and described 40 rotating virtual rose bush videos. Non-metric Multidimensional Scaling (MDS) results for both panels were similar and allowed us to highlight five groups of virtual rose bushes with their specific sensory characteristics and their own most representative products using a combination of the paragons and the most typical products. This approach revealed that subjects detected high visual differences between products, and that by using rotation, they were able to integrate 3D properties about variations around plant facets. Finally, a labeled sorting task is a powerful method for preliminary exploration of the visual aspect of virtual plants.

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Introduction

The visual quality of ornamental plants is a specific criterion that plays a major role in the purchase triggering. This quality stands on visual characteristics tightly linked to a 3D component that is the plant architecture which results from the characteristics and the spatial organization of the aerial organs (Boumaza, Demotes-Mainard, Huché-Thélier, & Guérin, 2009; Morel, Galopin, & Donès, 2009). Impacts of growing practices on some architectural parameters are well-known for numerous plant species. Nonetheless, growers and breeders make use of them more or less empirically, and resulting effects on visual properties from a sensory point of view still poorly studied (Crespel, Le Bras, Relion, & Morel, 2014; Huché-Thélier et al., 2011).

Recently, Boumaza et al. (2009) transposed the sensory approach to the ornamental field with one of the most famous ornamental plants as model: the rose bush. This approach made it possible to select sensory attributes according their unambiguity, discrimination power, and independence using plants directly as stimuli. For some sensory attributes about shape properties like "top-sided shape", "rounded form", "shape filling" and "plant compactness", the subjects were asked to look only one plant facet: the one with the plant label visible. For the others attributes, subjects were allowed to turn the plants around, but this was not a requirement. Unfortunately, this study did not make it possible to integrate the plant 3D in the reduced final list of sensory attributes. Using single facet picture of plants as stimuli, following sensory studies on rose bushes based on the previous of Boumaza et al., (Boumaza, Huché-Thélier, Demotes-Mainard, Le Coz, & Nathalie, 2010; Huché-Thélier et al., 2011; Santagostini et al., 2014) have discarded the plant 3D. However, plants have multiple facets, and the sensory perception of this should be investigated. Furthermore, architectural variations among a single rose bush crop composed of plants from the same cultivar and grown in the same conditions could be high (Demotes-Mainard et al., 2013). The implications of this variability among such crops need to be studied to better understand how much this variability could impact plants' visual properties, and to target the key architectural parameters related thereto.

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Using plants from a same cultivar grown in a unique environment recorded on video while rotating as stimuli for sensory evaluations could be therefore an interesting way to investigate: (i) if the human eye can distinguish visual differences among such a crop; and (ii) if it integrates or not the plant 3D for the characterization. For this, using virtual modeling represents an efficient alternative to counteract some limitations that occurs with real plants and photographs like for presenting the plants' various facets or defoliated plants as mentioned by Boumaza et al. (2010). Indeed, virtual plant modeling offers many advantages for various experimental issues (Heuvelink, Tijskens, & Kang, 2004). It enables a quick generation of large samples that can be visualized and manipulated in 3D on computer screens. Virtual plant growth can be easily monitored, controlled and stopped with various parameters. Also, architectural parameters of virtual plants can be directly obtained from the modeling process, whereas it is very time-consuming and tedious on real plants (Crespel, Sigogne, Donès, Relion, & Morel, 2013). In addition, using virtual plants does not involve growing costs, and allows taking and moving them readily thanks to data storage devices.

In this context, using *Rosa hybrida* as a model, our research project aims to better understand the dynamic relationships existing between the architectural construction of the bush and its visual appearance. For this, an objective and suitable method for visual characterization of virtual and real plants that integrate their 3D is needed. In the present paper, a first attempt to use as stimuli virtual rotating plants generated from architectural data of a single rose bush crop for a sensory evaluation of their visual appearance is presented.

The sensory profile derived from the quantitative descriptive analysis (QDA®) methodology (Stone, Sidel, & Singleton, 1974) is a well-known suitable tool to explore sensory properties of complex products. It could have been used first, however before establishing a sensory profile, it is important to know if the product space studied presents perceptible differences. Otherwise, there is no reason to do so (Strigler, Touraille, Sauvageot, Barthélémy, & Issanchou, 2009). This is particularly relevant when studying genetically identical plants grown in the same environment. Thus, a labeled sorting task *i.e.* a free sorting followed by a verbalization task (Bécue-Bertaut & Lê, 2011) was preferred for a first attempt. This sensory procedure appears to be a quick and effective way to characterize a such product space, and could provide solid bases for guiding subsequent analyses such as sensory profiles (Chollet, Lelièvre, Abdi, & Valentin, 2011). The sorting task has been tested on various types of products and has proved itself to be an effective, well-established method that makes it possible to know if a product space shows an underlying perceptual or conceptual structuring. This task requires little time and people who are familiar with the product field but not necessarily trained (Abdi, Valentin, Chollet, & Chrea, 2007; Chollet et al., 2011; Varela & Ares, 2012). It is a suitable method to reveal eventual differences and similarities within a large sample. Indeed, Bijmolt and Wedel (1995) showed that when using free sorting compared to other discriminative tasks (paired or triadic comparisons, conditional ranking), subjects expressed less fatigue, less boredom, better task insight, and they took less time to complete the task. Nevertheless, sorting tasks alone do not provide any information about the properties used by the subjects to evaluate the products. Thus, a verbalization task could follow the sorting in order to interpret the eventual underlying structure of the product space (Chollet et al., 2011; Faye, Courcoux, Giboreau, & Qannari, 2013). Therefore, a labeled sorting task was judged to be an appropriate method to investigate quickly if it is possible: (i) to use videos of rotating virtual plants as stimuli; (ii) to perceive visual differences among plants from a same cultivar and grown in the same conditions; and (iii) to integrate the plant 3D in the characterization.

Materiel and methods

Sample collection: Rotating virtual rose bush videos

Forty rotating virtual rose bush videos (referred to below as virtual rose bushes or products) were collected (see Video 1 for an example of a rotating virtual rose bush video and Fig. 1 for a frame still of this video). To obtain these virtual rose bushes, data from an architectural analysis of five-month old 'Radrazz' (a *Rosa hybrida* cultivar marketed under the name of Knock Out®) cultivated under controlled non-restrictive conditions were used (Morel et al., 2009). These data made it possible to create a matrix for a normalized plant that combine according to the location of the buds: (i) the probability of bud break; and (ii) the probability that the bud break give a short or long axis. The matrix and its usage rules presented thereafter, were then implemented in a former virtual plant structural model of the 'Radrazz' cultivar (Favre et al., 2007) built using L-studio, a Lindenmayer system-based plant-modeling software (Karwowski & Prusinkiewicz, 2004), making it possible to generate rotating plants *in silico* using a structural and probabilistic model. Then videos of the rotating plants were recorded with CamStudio™, a free screen-recording software (CamStudio., n.d.).

More precisely, this model considers short and long axes respectively composed of 3 and 9 metamers, each formed by an internode, a node, a leaf and a bud. Axes are edified by vegetative terminal apexes which turn at the end of their growth into flowers and then into fruits. The modeling process starts by the growth of a first branching order 1 long axis. Then, a random selection ordered according to the decreasing bud break probability of each metamer is done to sample which buds give branching order 2 axes. A second random selection is done to sample which bud breaks give long or short axes. At each new branching order edified, the numbers of long and short axes of the current step are compared to respective minimum and maximum threshold values. If thresholds are not fulfilled, the algorithm discards the axes and restarts the random selections on the inferior branching order until it does. Then the process continues until the plant has formed branching order 5 axes.

Since data of Morel et al. (2009) were obtained from plants of the same cultivar grown in the same conditions, the modeling process reflects thus the architectural variability within a similar crop.

Subjects

Thirty-four volunteers closely linked to the horticulture sector were recruited from the Research Institute on Horticulture and Seeds (RIHS), the French Group for the Study and Control of Varieties and Seeds (GEVES), and the French Institute for life, food and horticultural sciences and landscaping (Agrocampus Ouest), none of whom had followed specific training for this experiment. The subjects were divided into two panels on the basis of their background characteristics (Table 1): panel 1 composed of 16 students (94% under 26 years old), and panel 2 composed of 18 engineers, researchers and technicians (94% over 26 years). This strategy was chosen for two reasons: (i) a priori, the two panels differ on the basis of their horticultural product knowledge; (ii) the availably of the subjects did not allow a repetition, thus comparison between panels could be used for the task reproducibility assessment.

Sensory test conditions and procedure

The test took place in computer labs with identical 17'' CRT monitors configured with their optimal preset 1600×1200 resolution. The subjects were placed on individual workstation sufficiently spaced from each other to avoid communication between them. Virtual rose bushes were coded with three-digit numbers

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