Effects of trial and error and social learning on flavour palatability in nursery pigs

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ABSTRACT

The acquisition of behaviours that enhance the acceptability of new feeds could improve the performance and animal welfare in the pig industry. Pigs may learn individually by trial and error and/or by social learning to consume and prefer new flavoured feeds. However, there is little information regarding the effects of learning on the palatability of those flavours. This study aimed to investigate possible changes in pigs' hedonic responses, estimated by the mean consumption time per approach (CT/A), for flavours previously learnt through individual experiences (Experiment 1) and socially by a brief interaction with an experienced conspecific (Experiment 2). A total of 96 nursery pigs were used to study their preference, acceptability and palatability for flavours previously conditioned. Flavours were associated with 4% sucrose (Experiment 1) or with a demonstrator that recently consumed the flavour (Experiment 2). Those flavours or positive conditioned stimulus (CS+) were compared with control flavours that were not positively conditioned (CS-). In experiment 1, pigs preferred ($P = 0.010$) and tended to accept more ($P = 0.069$) of the CS+ than CS- in water solutions. Nevertheless, no palatability differences were found ($P = 0.875$). In experiment 2, observer animals had a higher intake of CS+ following interaction with demonstrators that consumed the same flavoured feed ($P = 0.041$). Snout to snout interaction time between those demonstrators and observers tended to present a positive correlation with CT/A ($r = 0.497$, $P = 0.1$). Thus both individual trial and error learning, and social learning, increased pigs acceptance of, and preference for, food flavours. However, only social Learning modified the pattern of consumption with the observation of a correlation between changes in the CT/A ratio and the degree of snout to snout contact time between demonstrators and observers. Thus the mechanisms and effects of social and individual learning appear to differ at least partially. Regardless of mechanism, the fact that associative learning can increase food flavour consumption suggests that interventions based on associative learning may be beneficial for addressing welfare problems in pig production linked to low consumption, in particular with respect to weaning where the low consumption may relate to the inexperience of the animals.

Keywords: associative learning; feeding behaviour; palatability; pigs; social learning; trial and error learning

1. Introduction

Learning plays a significant role in food selection through the acquisition of individual preferences for associated sensory cues that predict oral and post-oral rewards of food (Sclafani, 2004). When animals learn to consume new foods by trial and error learning, flavours associated with those foods may act as conditioned stimuli. The flavour of the food is associated with the positive or negative consequences of consumption (unconditioned stimuli), generating a future attraction or rejection for the associated flavours (Ackroff and Sclafani, 2010). However, environment exploration requires expenditure of time and energy, exposing animals to potential predators or toxins (Laland, 2004). In contrast, social learning facilitates the acquisition of highly adaptive food information, typically from conspecifics, thereby minimizing the costs implied by trial and error learning (Nicol, 1995). Animals can learn to consume foods through imitation, monitoring of the consumption site or joining other more experienced animals during a consumption episode (Galef and Laland, 2005). Thus, through social learning animals can learn flavour preferences (Galef and Whiskin, 2008), the location of food sources (Held et al., 2000), and to avoid noxious foods (Laland, 2004).

Under commercial conditions, pigs are faced by nutritional challenges that may affect their subsequent productive performance (Main et al., 2004). At weaning, pigs are reluctant to eat new feeds, often resulting in a period of underfeeding or anorexia with consequent diarrhoea and poor growth, resulting in reduced welfare (Oostindjer et al., 2014). Learning about foods before weaning could be a useful strategy to reduce these detrimental effects by improving the acceptability of new feeds or flavours. Previous experiments have shown that pigs prefer flavours learned by both individual trial and error (Clouard et al., 2012; Figueroa et al., 2012a) and by social learning (Held et al., 2000; Figueroa et al., 2013). However, learnt flavour preferences could be explained by many changes, including motivation or by changes in the pleasure perception or palatability of that flavour at the time of consumption (Dwyer, 2008, 2009).

Experiments in rats have evaluated palatability through orofacial reactions at the time of consumption (Grill and Norgren, 1978), short-term consumption (Boughter et al., 2002), and analysis of lick cluster size (Davis and Smith, 1992; Dwyer, 2008). Palatability has been studied in pigs through the analysis of consumption patterns (Figueroa et al., 2019), analogous to lick cluster size analysis in rats, where the consumption time (CT) divided by the number of approaches (A) to the site of consumption is assessed (CT/A). However, little information exists regarding the effects of learning on the palatability of a flavour in pigs (Forbes, 2010; Clouard et al., 2014). Experiments in rats demonstrate that when a flavour is associated with carbohydrates, such as sucrose or maltodextrins, the palatability of the associated cues increases (Forestell and LoLordo, 2003; Dwyer, 2008). However, there is little information about the effect of social learning on flavour palatability. Recently, Figueroa et al. (2020a) did not find hedonic changes in rats' flavour perception after interacting with a conspecific that recently consumed a flavoured solution.

The aim of this study was to investigate possible changes in pigs' responses (in terms of preference, acceptability and palatability) for flavours previously learnt during a training period by individual trial and error experiences (Experiment 1) and socially by a brief interaction (30 min) with a conspecific that recently consumed those flavours (Experiment 2).

2. Materials and methods

Experiments were conducted at the nursery unit of Pontificia Universidad Católica de Chile pig facilities. The experimental procedures were approved by the Ethical Committee on Animal Experimentation of the Facultad de Ciencias Veterinarias y Pecuarias at the Universidad de Chile, certificate Nº 252014.

2.1 Experiment 1: Flavour conditioned palatability after individual trial and error learning

2.1.1 Animals and housing

A total of 32 castrated male and female nursery pigs were used (PIC® genetics, Hendersonville, Tennessee, USA). Animals (weaned at 21 days; 6.094 ± 0.148 kg) were transported from a commercial pig farm (Metropolitan de Santiago region, Chile) to the swine experimental facilities experimental nursery facilities belonging to the university. They had been offered an unflavoured creep-feed diet during the suckling period from day 10 using a commercial pan feeder at the commercial farm. On arrival at the experimental facility, animals were individually identified using numbered plastic ear tags and were randomly allocated into 16 fully slatted pens (2 pigs/pen; 1.28 m x 1.8 m x 0.7 m). The pens had full walls, therefore the animals in each pen had no visual or tactile contact with the animals from other pens during the whole experimental procedure. The nursery room was equipped with automatic forced ventilation and controlled environment temperature (27.3 ± 2.70° C). The animals had ad libitum access to a commercial powder feed offered with a hopper feeder with 3 feeding spaces according to their nutritional requirements (NRC, 2012) and water provided by stainless steel nipples. Hanging steel chains were used as environmental enrichment during the nursery period but there were removed during the experimental period. Before experimental procedures started, pigs were acclimated for one week to the new environment and management conditions.

2.1.2. Experimental procedure

After the acclimation period, animals were trained to drink during 8 days (alternate sessions) a flavoured solution (CS+Suc) that was mixed with 4% sucrose and a different flavoured solution (CS-) mixed in water. Flavour products used as CSs (garlic or aniseed, 0.075%; Floramatic ®, Santiago, Chile) were selected because of their similar preferences in naive animals and were balanced across pens to act as CS+ or CS- flavours. Thus half of the pens (Group 1, 8 pens) were trained to drink garlic flavoured solutions mixed with 4% sucrose during sessions 1, 3, 6 and 8, while the remaining pens (Group 2, 8 pens) were exposed to the garlic flavour solution without sucrose at those sessions. During the other 4 sessions (days 2, 4, 5 and 7), half of the pens (Group 2, n8) were trained to drink an aniseed flavoured solution mixed with 4% sucrose, while the remaining pens (Group 1, n8) were exposed to aniseed flavoured solution without sucrose. Training sessions involved giving one experimental pan with 800mL of the respective CS solution at 10:00 am at the front of each pen for 30 min/day. Animals were feed and water restricted for 1 hour before sessions and no feed or water was available during the training. Consumption was measured by calculating the difference between the initial and final weight of the pans.

Flavour preference, acceptability and palatability for CS+ and CS- flavours were estimated in each pen on days 10 and 11. Flavour preferences were assessed using a two-choice test. Pig pairs were exposed for 30 min to two equidistant pan-feeders simultaneously placed in the front of each pen containing the CS+ and CS- flavoured solutions without sucrose. The right-left position of the CS+ and CS- flavours was balanced across subjects and days: half of the pens of each group received the garlic solutions at the right position the first day and aniseed solutions at the left position. In the other half of pens of each group, aniseed solutions were at the right position and garlic solutions at the left position. The flavour positions were swapped on the second test day. Subsequently, the acceptability of that flavours (CS+ and CS-) was estimated on two consecutive days (experimental days 12 and 13), where the animals received a single pan placed in the front of each pen containing one of the flavoured solutions (without sucrose) for 30 min, balancing the flavours (CS+ and CS-) between animals and days**.** One hour of feed and water restriction was applied before each test and no feed or water was available during the test.X

Intake was measured by calculating the difference between the initial and final weight of the pans during each preference and acceptability test. Usually, solution spillage was not significant and was not accounted when measuring consumption. Additionally, the behaviour of the pigs in term of consumption time and number of approaches to the pan was recorded simultaneously during the first 10 min of the acceptability test by focal continuous sampling using one video camera (IR

Outdoor Cameras 700tvl 1/3 cmos Sony, SENKO SA, Santiago, Chile) placed in a central position on the ceiling of each pen. The CT/A was estimated based on study of Figueroa et al. (2019) as the total time in which the animal drinking at the pan (i.e. consumption time) divided by the number of times the pan was approached with a consumption result (i.e. number of approaches). For each pen, one video camera was used. Additionally, analyses of the first (0 to 5 min) and the final (6 to 10 min) half of the period were performed to examine whether these sub-periods of the session would be more sensitive than the session as a whole in estimating palatability.

2.1.3. Statistical analysis

Consumption from each pen (pair of pigs) during the training sessions and at the preference, acceptability and palatability tests after training were analysed by mixed linear models with the MIXED procedure of the statistical package SAS 9.4 (SAS Inst. Inc., Cary, NC), taking into account for training sessions the solution consumed (CS+Suc or CS-), the flavour consumed (garlic or aniseed), the training session (1-4) and the interaction between factors. For preference and acceptability test the main factors considered were the solution consumed (CS+ or CS-), the flavour consumed (garlic or aniseed) and their interaction. Finally, to estimate palatability, CT/A were analysed for the total period (0 to 10 min) and in each sub-period (0 to 5 min and 6 to 10 min), considering as the main factors the solution consumed (CS+ or CS-) and the flavour consumed (garlic or aniseed) and the interaction between factors. Interactions that were not significant were removed from the final model. Pen was included as a random effect. Each pair of pigs were considered as an experimental unit. Prior to ANOVA analysis, normality and homoscedasticity of dataset were analysed by using the UNIVARIATE procedure with the Shapiro Wilk and O'Brien's test, respectively. As no significant p-values were obtained for any of the specific factors, the original hypothesis for normality and homogeneity of variance were accepted ($P>0.10$). Results are presented as LSMeans ± SEM, considering a significance level of 5% adjusted by Tukey. A trend in the data was defined as $0.05 \leq P \leq 0.1$.

2.2 Experiment 2: Flavour conditioned palatability after social learning

2.2.1 Animals and housing

A total of 64 castrated male and female nursery pigs (PIC® genetics, Hendersonville, Tennessee, USA), weaned at 21 days of life and weighing 6.088 ± 0.209 kg were used. The origin of animals, transport, identification and husbandry conditions were the same as in Experiment 1 with the exception that pigs were allocated in groups of 4 to the 16 nursery pens.

2.2.2 Experimental Procedure

Experimental procedures are summarized in **Figure 1.** After the acclimation period, two pigs from each pen (16 pig-pairs) were randomly selected to act as demonstrators (DEM) and were temporary removed and allocated to 16 pens (identical to their home pens in a neighbouring room). DEM were then *ad libitum* fed with a flavoured commercial diet (0.075% aniseed or garlic flavours (Floramatic ®, Santiago, Chile)) for 30 min; eight pairs were exposed to garlic flavour and the remaining eight to aniseed in order to balance the experimental design.

DEM pigs were returned to their original pens to interact with pigs that remained there (observers; OBS) for 30 minutes. After the interaction period between DEM and OBS, DEM pigs were removed again and OBS were exposed to a pan-feeder with garlic feed for 30 minutes placed in the front of each pen. This was repeated 24 and 48h later in order to estimate the extinction of the expected change in observers' feeding behaviour. Before each test, animals underwent one hour of feed and water restriction. No commercial feed or water was available during the test. Feed intake was estimated by calculating the difference between the initial and final weight of the pans for each acceptability test. Feed waste was not significant and was not accounted when measuring consumption. As in experiment 1, OBS pigs were video recorded (16 Video-cameras, IR Outdoor Cameras 700tvl 1/3 cmos Sony, SENKO SA, Santiago, Chile) during the first 10 min. of their exposure to garlic diets and behaviour was analysed by focal continuous sampling in order to estimate CT/A (Figueroa et al., 2019). This was used as a possible indicator of changes in the hedonic perception for the flavoured food. Additionally, analyses of the initial (0 to 5 min) and the final (6 to 10 min) half of the period were performed to examine whether these sub-periods of the session would be more sensitive than the session as a whole to estimate palatability. Moreover, the time spent on oro-nasal contact between DEM and their respective OBS during the interaction period was measured to study possible correlations between interaction time and the magnitude of the expected effect on OBS feeding behaviour, reflected in animals' CT/A, consumption time and number of approaches during the complete period of the test (0-10 min), the initial (0 to 5 min) and the final (6 to 10 min) half of the test. In order to assess the time of oro-nasal contact more accurately between DEM and OBS, the video-cameras were installed on ceiling of each pen to capture from an upper view the physical contact between animals. The oro-nasal contact was defined when an observer pig touched the end of the snout of the demonstrator pig with the end of its own snout and vice versa.

2.2.3. Statistical analysis

Consumption data of each DEM and OBS pairs and the palatability measures of OBS pairs were analysed by mixed linear models with the MIXED procedure of the statistical package SAS 9.4 (SAS Inst. Inc., Cary, NC), taking into account in the case of DEM consumption the flavoured feed consumed (garlic or aniseed feed), and in the case of OBS consumption the flavoured feed consumed by their respective DEM (garlic or aniseed feed), the test day (1, 2 or 3) and the interaction between those factors. Finally to estimate OBS palatability, CT/A were analysed for the total period (0 to 10 min) and in sub-periods (0 to 5 min and 6 to 10 min), taking into account as the main factors the flavoured feed consumed by their respective DEM (garlic or aniseed feed), the test day (1, 2 or 3) and the interaction between those factors. Moreover, Spearman correlations were calculated between the oro-nasal interaction time of DEM and their respective OBS, and the CT/A and their components (consumption time and number of approaches to the pan) of those OBS during the complete period of the test and sub-periods. Before ANOVA analysis, normality and homoscedasticity of dataset were analysed by using the UNIVARIATE procedure with the Shapiro Wilk and O'Brien's test, respectively. As no significant p-values were obtained for any of the specific factors, the original hypothesis for normality and homogeneity of variance were accepted ($P > 0.10$). Results are presented as LSMeans ± SEM, considering a significance level of 5% adjusted by Tukey. A trend in the data was defined as $0.05 \leq P \leq 0.1$.

3. Results

3.1 Results Experiment 1: Trial and error learning

3.1.1 Training sessions

Animals increased their solution intake as the days increased [$F(3, 15) = 21.29$, $P < 0.001$]. Overall intake was higher for CS+Suc than CS− solutions [$F(1, 15) = 16.44$, $P = 0.001$]. Intakes of CS+Suc and CS− during the training sessions are shown in **Figure 2.** There was an interaction between testing days and solutions [Day×CS, $F(3, 15) = 8.24$, $P = 0.002$], were the intake of CS+Suc increased over training sessions exceeding the consumption of CS− only in session 4 ($P = 0.004$; days 7 and 8) but not in the first 3 sessions, were a trend to consume more CS+Suc was observed in sessions 2 ($P = 0.078$) and 3 ($P = 0.109$) and no differences between solutions intake were observed during the first session ($P = 0.228$). The flavour used also had an effect on consumption ($P < 0.001$) irrespective of whether the solutions included sucrose [$F(1, 15) = 28.39$, $P < 0.001$]. Pigs drank more when garlic was added into solutions (292 vs. 210 g; SEM 15.36 g) The differences between flavour consumption also increased with time, reflected in a significant interaction between flavour and session day [$F(3, 15) = 20.75$, $P < 0.001$].

3.1.2 Flavour preference, acceptability and palatability

The preference, acceptability and palatability for CS+ and CS- solutions after training are summarized in **Figure 3.** According to the preference test, pigs preferred the CS+ over the CS− [$F(1, 15) = 8.60$, $P = 0.010$] **(Figure 3a).** Moreover, when pigs were offered only one CS option (CS+ or CS- on different days), they consume more CS+ than CS- solutions [$F(1, 14) = 6.69$, $P = 0.022$], **(Figure 3b).** Nevertheless, no differences were found between the CS+ and CS- CT/A [$F(1, 15) = 0.01$, $P = 0.913$] **(Figure 3c),** at any of periods analysed ($P > 0.05$). Finally, the flavour tested (garlic or aniseed) had an effect on pigs acceptability [$F(1, 14) = 6.58$, $P = 0.022$] and preferences [$F(1, 15) = 48.87$, $P < 0.001$] observing a higher consumption of garlic over aniseed. Palatability was not affected by the flavour tested [$F(1, 15) = 0.03$, $P = 0.856$].

3.2 Results Experiment 2: Social learning

3.2.1 Flavour acceptability

The acceptability of garlic and aniseed flavoured feed by the DEM did not differ [137 vs. 166g, SEM 22.9g; $F(1, 15) = 0.77$, $P = 0.394$]. **Figure 4a** shows the acceptability of the garlic feed by the OBS on day 1, 2 and 3 according to the flavour consumed by their DEM. After the interaction with DEM pigs, the general consumption of garlic feed was higher in OBS pigs that had interacted with DEM who had consumed garlic [$F(1, 13) = 5.12$, $P = 0.041$]. Consumption did not show differences between days [$F(2, 13) = 1.07$, $P = 0.371$]. The interaction between the flavour consumed by the DEM and the day of the test did not have an effect on the consumption of garlic flavoured feed by the OBS [$F(2, 13) = 0.13$, $P = 0.878$].

3.2.2 Flavour palatability

Palatability of observers for the garlic flavoured feed, expressed by CT/A is presented in **Figure 4b.** No effect of the flavour consumed by demonstrators (garlic or aniseed) [$F(1, 13) = 0.69$, $P = 0.421$], day of the test [$F(2, 13) = 2.13$, $P = 0.159$] or the interaction of these factors [$F(2, 13) =$

0.23, P = 0.796] were observed. The day of the test had an effect on CT/A in the first half of the test (0 – 5 min) [F(2, 13)=5.19, P = 0.022], increasing with time. However, no effect was observed during the second half of the test (6-10) [F(2, 13)=0.48, P = 0.629]. Finally, palatability was not affected by DEM flavour consumed or by the interaction between the day of the test and the flavour consumed by the DEM in any of the periods analysed (P > 0.05).

3.2.3 Snout to snout interactions

The correlation between snout to snout interaction time between DEM and their respective OBS, and OBS' approaches, consumption time and CT/A for garlic feed during the sub-periods are shown in **Table 1.** This analysis was performed separately for the garlic and aniseed DEM groups. Most interestingly, when looking at the correlation between CT/A (palatability) and the DEM-OBS interaction, a positive but moderate correlation for observers that interacted with demonstrator that consumed garlic feed, over the first 5 min of the sessions (and a trend to the same effect over the whole 10 min analysis period), was observed. Critically, this relationship was entirely absent in observers interacting with demonstrators that consumed the aniseed flavour which was not used during the test sessions. Although not significant, results suggest that the correlation between DEM-OBS interaction times and CT/A (consumption time/number of approaches) was driven by both a positive correlation with consumption time and a negative correlation with number of approaches (**Figure 5).**

4. Discussion

Pigs are able to acquire new flavour preferences by trial and error and social learning, allowing them to anticipate future oral and post-oral rewards. This was confirmed in Experiments 1 and 2, which also extended the analysis to the palatability of the learnt solutions. On the other hand, our results gives certain evidence for a change in palatability, finding little evidence of changes due to individual learning, but a suggestion of changes in palatability associated to social learning.

4.1 Individual trial and error learning

As in previous experiments, in the present study nursery pigs preferred flavours previously conditioned with energy compounds such as sucrose (4%). Results suggest that both the palatable taste and post-ingestive effects of sucrose contributed to the conditioned CS+ preference and acceptability, reflecting how attractive the sucrose is to pigs (Glaser et al., 2000). Figueroa et al. (2012b) associated a flavoured solution with sucrose (4%) observing that sucrose post-ingestive effect by itself may condition flavour preferences, noting a higher intake than flavours conditioned with the same sweetness but a minor energy level (1% sucrose + 0.08% saccharine). Similar results have been observed in pigs when other concentrations of sucrose (10%) or carbohydrates as maltodextrin (2.25%) were used as a reinforcement (Clouard et al., 2012). This could indicate that post-ingestive effects might be sufficient to condition flavour preferences as several experiments showed in rats (Lucas et al., 1997; Ackroff and Sclafani, 2010). Figueroa et al., 2012a also reported protein-based flavour preference conditioning in pigs, where animals associated protein concentrates (> 60% CP) with artificial flavours during nursery. They showed a clear preference when those flavours were presented later in water solutions or commercial feed. Regarding acceptability of previously conditioned flavours, in the present study we observed that animals present a higher consumption of those flavours when only one option was offered. Despite the existence of evidence in rats (Pérez et al., 1998), previous experiments in pigs did not explore the effect of learning on flavour acceptability. This information could be useful to extrapolate to real commercial conditions where only one feed option is provided. However, the possible learning extinction and long-term effect of flavour consumption still needs to be explored.

Experiments in rats support that flavours conditioned by the post-ingestive effects of nutrients not only are better preferred and accepted, but also are perceived as more pleasant (Myers and Sclafani, 2001). Diverse measures correlated with the palatability of a solution or feed, such as licking pattern, appetitive facial expressions and consumption in a brief period of time observing an increase when flavours are previously associated with the benefits of sucrose or maltodextrins (Forestell and LoLordo, 2003; Dwyer, 2008). However, palatability in pigs to date has not been systematically studied. Clouard et al. (2014) observed changes in behavioural activities, motivational responses and microstructure of CS intake in nursery pigs after they had been conditioned with 16% sucrose. Added to this, a non-significant higher duration of drinking episodes and a smaller number of drinking episodes were observed. This information could be extrapolated to lick cluster size analysis in rats (Davis and Smith, 1992) or CT/A in pigs (Figueroa et al., 2019), suggesting the importance of oral perception of the unconditioned stimulus (US) during training for possible hedonic changes for the CS+ in pigs. However, no changes in palatability were observed in the present experiment after conditioning flavours with 4% sucrose. A possible explanation could be that rather than acquiring the hedonic tone of the US, the CS+ acquires the incentive value of the US (perhaps because of the low concentration of sucrose used). This can maintain an elevated intake, reflected in preferences and acceptability even in the absence of enhanced palatability (Myers and Sclafani, 2001). However, there is also evidence from rats that conditioned changes in palatability are relatively short-lived (e.g. Dwyer et al., 2009). Thus, learned changes in flavour palatability may have extinguished before because the palatability tests followed preference tests delivered without sucrose.

4.2 Social learning

The changes in pigs' feeding behaviour induced by social learning through brief interactions have been previously studied in terms of preferences (Figueroa et al., 2013, 2020b). The present study explored the effects of social learning on pigs' flavour acceptability and palatability, highlighting the importance of oro-nasal contact in the acquisition of new feeding patterns, which has been previously reported by Galef and Stein (1985) in rats. Results show that, similar to rats, the acceptability of a flavoured feed increases after a brief contact with a familiar demonstrator that previously consumed that feed. This phenomenon could involve learning, establishing the acquisition of new feeding behaviours in the population that could remain dependent on the immediate reinforcement generated by the consumption of that flavoured feed, other consumption alternatives and population dynamics (Galef and Laland, 2005). Social learning could be a key strategy in productive stages where pigs exhibit feed neophobia, such as at weaning (Pluske et al., 2007). The interaction of the test day and flavour consumed by the DEM pigs did not show an effect on the acceptability of the flavoured food, therefore, no extinction of learning was observed, but rather, this was maintained (Galef and Whiskin, 1998).

Regarding palatability, although changes have been described after associative learning in several species (Dwyer, 2008, 2009), little information exists on changes in feed palatability after a brief social contact (Figueroa et al., 2020a). In the present experiment interesting results were obtained when analysing the first half of the test, similar to results observed by Figueroa et al. (2019). This suggests that the first 5 minutes of exposure to a feed is most sensitive in assessing hedonic reactions after associative learning. Palatability, contrary to acceptability, showed no overall changes when the DEM consumed the same flavour as presented to the OBS (garlic flavour), and it did change according to the test day, increasing over the days. The latter could be attributed to the fact that neophobia modulates palatability, due to both a habituation effect and the perception of feed as familiar and safe (Lin et al., 2012).

While there was no reliable change in overall palatability due to social learning, a correlation between palatability and the amount of snout to snout contact between OBS and DEM animals was observed. According to Galef (for a summary see Galef, 2012) an OBS rat acquires a new feeding behaviour by having a brief contact with an experienced DEM through its breath (Galef et al., 1988; Munger et al., 2010). Based on this, interaction between individuals, more specifically the time and number of oro-nasal interactions, is essential to generate changes in feed preferences in rats (Galef and Stein, 1985). Although the specific components of pigs' breath were not isolated in the present experiment, when studying the oro-nasal contact time between DEM and OBS, it was found that it was positively correlated with the CT/A. Critically, this was only seen when the OBS animals were tested with the same flavour as consumed by the DEM animals (and thus the correlation cannot be due to animal temperament factors that would affect both snout to snout contact times and CT/A in the same way). This implies that the longer the oro-nasal contact time between OBS and DEM, the greater the subsequent palatability of the flavoured feed. This suggests that in pigs there would also be chemical compounds from their oro-nasal cavity that, in a given context (flavoured feed and presence of a conspecific), would be responsible for the changes in feeding behaviour described in this experiment. However, further studies are required to clarify the responsible mechanism of these changes in pigs' feeding behaviour.

5. Conclusions

Learning based on individual experience or social exposure can change the feeding behaviour of pigs, presumably on the basis that previously novel flavours come to be associated with positive events such as calories or social interaction. We conclude from our experiments that trial and error and social learning are important contributors to pigs' preferences and acceptability for flavours learnt. Nevertheless, only social learning modified the hedonic perception of flavours, with an interesting correlation between snout to snout contact time between DEM and OBS and the magnitude of OBS changes in their hedonic perception for those flavours. Therefore, the mechanisms that are involved in the oro-nasal-contact mediated social interaction in pigs, have to be further explored to better understand the changes of feeding behaviour observed in this study. Regardless of the exact mechanism of learning, it is clear that associative learning (based on either individual or social experiences) can lead in increases in the consumption of, and preference for, food flavours. Thus interventions based on associative learning about food flavours could be beneficial to implement on pig farms to help increase food consumption. This would be especially true around periods of change in the production stages (in particular weaning) because these are particularly stressful and associated with reductions in feed intake and welfare.

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Table 1. Spearman's correlation between snout to snout interaction time of demonstrators (DEM) pigs that previously consumed garlic or aniseed flavoured feed with their respective observers and consumption time (CT), the number of approaches (A), and CT/A of those observers against garlic flavoured feed analysed during the complete period of the observer test (0-10 min), the first half (0-5 min) and the last half (6-10 min).

	Garlic DEM		**Aniseed DEM**	
	r	***p***	**r**	***p***
Consumption time (CT, s)				
0-5 min period	0.388	0.211	0.151	0.638
6-10 min period	0.302	0.334	-0.129	0.688
0-10 min period	0.410	0.185	0.000	1.000
Number of approaches (A)				
0-5 min period	-0.475	0.118	0.390	0.210
6-10 min period	-0.227	0.477	0.529	0.076
0-10 min period	-0.518	0.084	0.422	0.172
CT/A				
0-5 min period	0.626	0.029	0.000	1.000
6-10 min period	0.388	0.211	-0.259	0.416
0-10 min period	0.497	0.100	-0.194	0.545

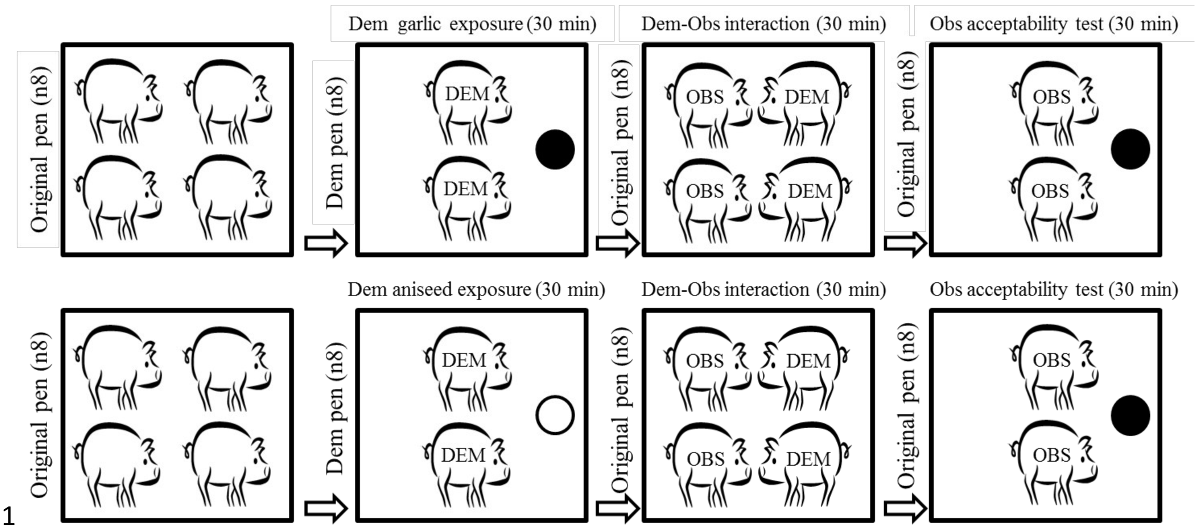

Figure 1. Experiment 2: Layout of the social learning procedures between observers (OBS) and demonstrators (DEM) pigs. Closed circles represent the garlic flavoured feed given to half of demonstrators (8 pig pairs) and the open circles the aniseed flavoured feed given to the other half of demonstrators (8 pig pairs). Observer animals were tested with an acceptability test where they were offered garlic flavoured feed.

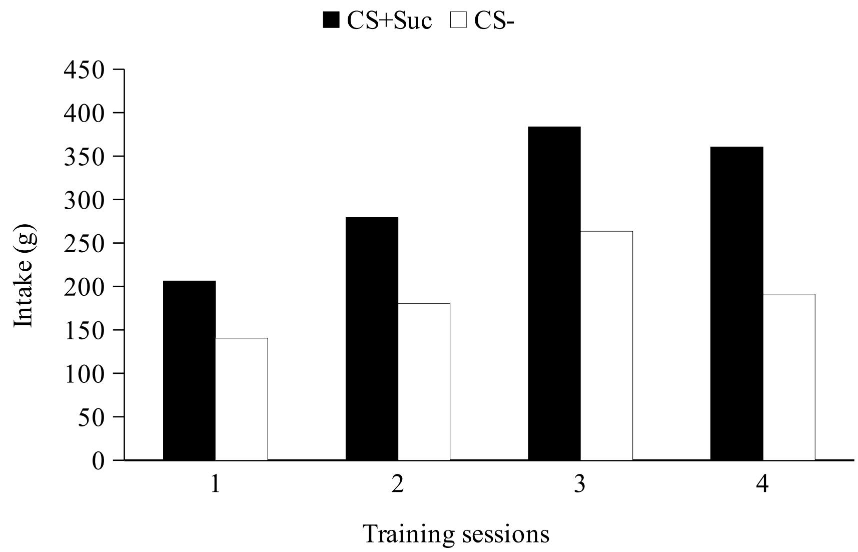

Figure 2. Experiment 1: Mean solution intake (+ SEM) of nursery pigs' pairs after 30 min. during training session for flavoured solutions (garlic or aniseed; 0.075%) with the inclusion of 4% of sucrose (CS+Suc) or without sucrose inclusion (CS−). No feed or other fluids were available during training sessions. †$P < 0.1$; *$P < 0.05$.

Figure 3. Experiment 1: Mean intake of CS+ and CS− solutions (+ SEM) during 30 min. non-reinforced two-choice test (a), during 30 min. non-reinforced one-pan acceptability test (b), and palatability estimated during the first 10 minutes (c) [consumption time (CT)/number of approaches (A)]. No feed or other fluids were available during the tests. *$P < 0.05$.

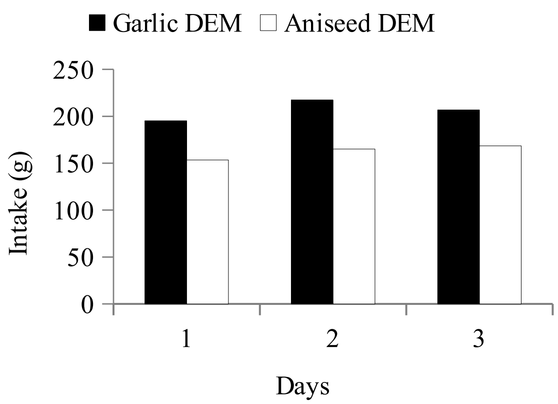

Figure 4. Mean consumption for garlic flavoured feed by observer nursery pigs that previously interacted during 30 min. with demonstrators (DEM) that consumed garlic (Garlic DEM) or aniseed (Aniseed DEM) flavoured feed (a) and palatability estimated during the first 10 minutes (c) [consumption time (CT)/number of approaches (A)]. Results are expressed by the day of the test. Flags: + SEM.

r = -0.518
p = 0.084

Figure 5. Experiment 2: Scattergrams of the number of approaches (a), consumption time (b) and consumption time per approach (c) of observers with garlic flavoured feed after interaction with demonstrators that previously consumed garlic flavoured feed, against snout to snout interaction times.